1981

The White Perch, *Marone americana* (Gmelin) in Nebraska

Gene Zuerlein
Nebraska Game and Parks Commission

THE WHITE PERCH IN NEBRASKA

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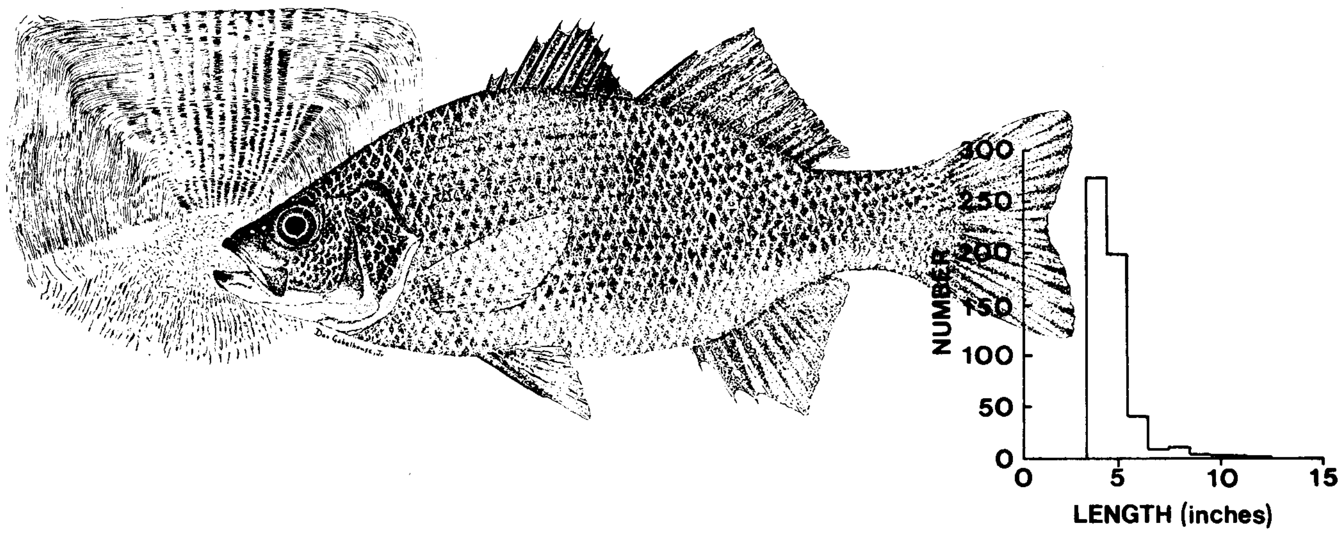

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NEBRASKA GAME AND PARKS COMMISSION
Eugene T. Mahoney, Director

THE WHITE PERCH, *Morone americana* (Gmelin) in NEBRASKA

by Gene Zuerlein

Nebraska Technical Series No. 8

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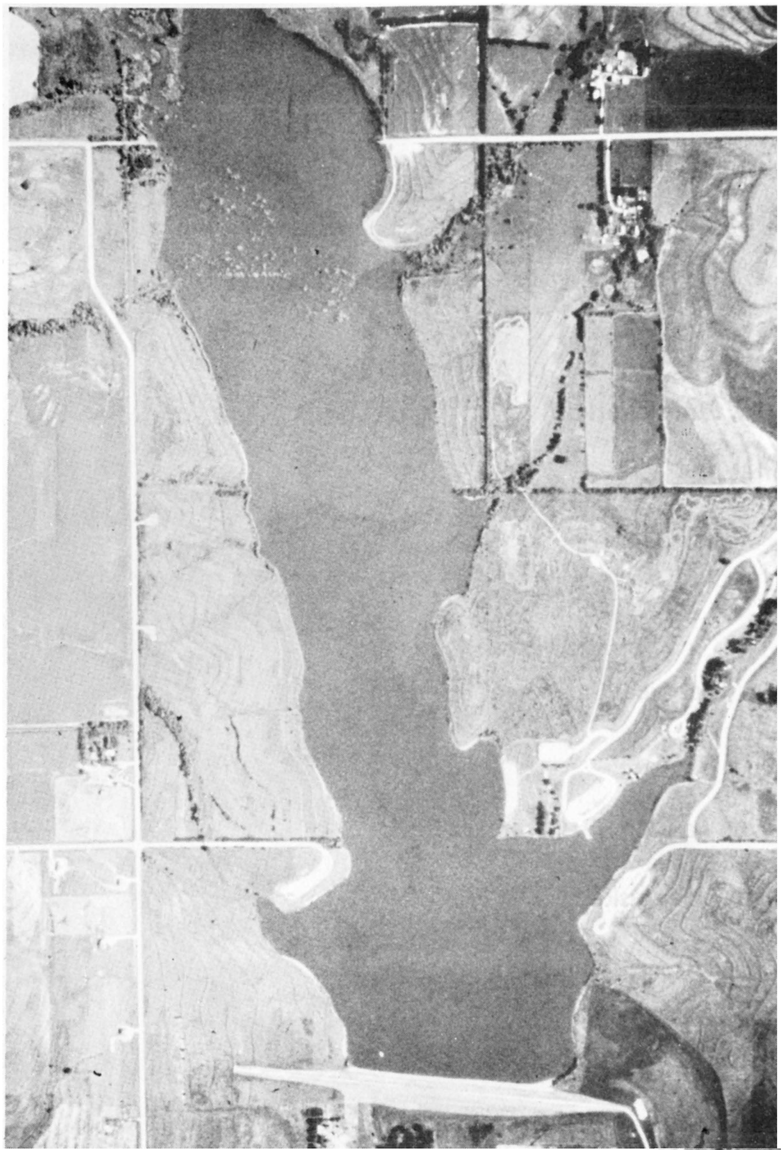
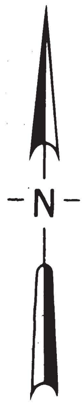


WAGON TRAIN RESERVOIR



STAGECOACH RESERVOIR

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INTRODUCTION

The white perch, *Morone americana* (Gmelin), is a member of the Percichthyidae family. It is a euryhaline species that is common along the northern Atlantic coast south to the Carolinas. Marine, estuarine and freshwater ecosystems with salinities ranging from 5 to 18 percent have been known to support white perch (Mansueti 1964). The species is semianadromous, making spawning runs up coastal streams. It commonly becomes completely landlocked in ponds and reservoirs of its native range where it spawns successfully. This species has been known as a game fish to generations of New England fishermen, but when stocked in landlocked waters white perch have a tendency to become overpopulated and stunted, thereby usurping the food supply and reducing the growth rates of other more desirable game species (Thorpe 1942, Everhart 1950, Stroud 1952).

In 1964 the white perch was brought into Nebraska in an effort to improve the sport fishery in a select group of alkaline lakes located in the Sandhills region. Adult perch were initially imported from New Jersey and allowed to spawn at the Valentine State Fish Hatchery. The progeny were used to stock the Sandhill lakes. In the fall of 1964 white perch young-of-the-year were discovered in Wagon Train Reservoir in southeastern Nebraska. Although the source of these fish is not definitely known, it appears they were inadvertently introduced as advanced fry in June, 1964 with a stocking of largemouth bass fry. In this reservoir white perch numbers increased rapidly. This expansion and other pertinent population and historical information has been reported in the literature (Hergenrader and Bliss 1971).

In 1971 white perch were discovered in Stagecoach Reservoir located approximately 6.4 km west-southwest of Wagon Train Reservoir in Lancaster County. Here the white perch population increased dramatically, clearly following the trends experienced in the Wagon Train white perch population. Because of their small size, most Nebraska white perch were undesirable to anglers. Factors which contributed to this situation included high fecundity, high natural mortality after Age III, and food preference.

When management endeavors to enhance the desirability of this species failed in both reservoirs, total renovations were conducted after reservoir drawdowns in 1975 for Wagon Train and in 1976 for Stagecoach. Subsequent to the above eliminations, Lund (1978a) discovered a large population of white perch in Buckley 3F Reservoir in 1977. The significance of this population in the Little Blue River watershed lies in the fact that it is entirely separate from the Salt Creek drainage where Wagon Train and Stagecoach are located. Like the latter two reservoirs Buckley 3F was chemically renovated in July of 1980. Efforts to contain white perch in Nebraska have been successsful on a lake by lake basis, but the species has spread to other lakes and streams. An update on the current distribution and potential for dispersal is covered by Hergenrader (1980). In addition to the documented locations of white perch by the above author this species also occurs in other localities, most noteworthy of which is Offut Air Force Base Lake, a -64 ha sandpit located along the Missouri River in Sarpy County. Results from a 1978 survey indicate reproduction has occurred. Fortunately, no natural reproduction of white perch has been documented in any Nebraska streams (Maret 1978).

The objective of this report is to summarize all data gathered by or available to Nebraska Game and Parks on white perch in Nebraska. Most of the data will involve Wagon Train and Stagecoach Reservoirs, but where applicable, comparisons were related to data collected on white perch in smaller reservoirs. Since total elimination of this species in Nebraska appears remote, this should assist future strategies to manage white perch.

Description of Study Reservoirs

Wagon Train and Stagecoach reservoirs are two of thirteen flood control impoundments constructed by the U.S. Army Corps of Engineers in the Salt Valley Watershed of southeastern Nebraska. All of the reservoirs are relatively shallow and their drainage areas consist primarily of agricultural and pasture lands. The naturally fertile soils, the widespread application of fertilizers to agriculture lands and the development of the livestock feeding industry, all contribute to a high level of nutrients in runoff waters. The impoundment of nutrient rich waters is resulting in accelerated eutrophication in the reservoirs (Hergenrader and Hammer 1973; Andersen and Hergenrader 1973; Hammer and Hergenrader 1973). Intermittent reservoir outflow occurs occasionally during spring runoff. Prevalent southerly winds, characteristic of the Plains region, prevent stable thermal stratification in the spring and summer.

Wagon Train Reservoir, completed in 1962, is fed by the north tributary of Hickman Branch of Salt Creek. This impoundment is located in Sections 25 and 36, T8N, R7E or approximately 23 kilometers (km) southeast of Lincoln. It has a surface area of 128 ha, a mean depth of 2.6 meters (maximum of 6 meters), and drains an area of 40.4 sq km. This reservoir is usually turbid due to fine soil particles kept in suspension by the prevailing winds. Numerous dead trees are present in the upper region of Wagon Train reservoir. Rooted aquatic vegetation is relatively sparse in this reservoir, but narrow bands of *Polygonum* and *Sagittaria* occur along the shore and in small shallow bays. Reed canary grass *(Phalaris arundinacea)* is also common along the shore. Wagon Train reservoir is used for fishing, waterfowl hunting, swimming, sailboating, and camping.

Stagecoach Reservoir, completed in 1964, is fed by two small intermittent tributaries to Salt Creek. Located in Section 4, T7N, R7E, this reservoir has an area of 79 ha, a mean depth of 3.0 meters (maximum of 5 meters), and drains an area of 25 sq km. The water in Stagecoach reservoir is relatively clear except during summer when large algal populations are present. Extensive beds of rooted aquatics *(Potamogeton pectinatus, P. americanus, Polygonum and Najas)* are found throughout the reservoir except for the deepest area near the dam. Stagecoach reservoir is utilized primarily for fishing and camping.

LITERATURE SURVEY

The white perch, *Morone americana* (Gmelin), was first classified as *Perca americana* by Gmelin (1788). Since then this species has been known by a variety of scientific names. Woolcott (1962) did an excellent review of the synonymy associated with white perch nomenclature as did Sheri (1968) and Beitch (1973).

Historically, this species inhabited coastal waters of the Atlantic Ocean. Pleistocene glaciers at one time limited its range to the present area of New Jersey and the coastal area south of it, but when the glaciers retreated white perch stocks moved northward until its range extended from the present Canadian Maritime Provinces of New Brunswick, Nova Scotia, and Prince Edward Island southward to South Carolina. This species is now considered native to salt, brackish, and freshwaters of this region (Vladykov and McKenzie 1935, Smith 1935, Anonymous 1962, Leim and Scott 1966). In the 1800's little biological information was known about many species of fish, including white perch. Consequently many endeavors to establish appropriate species in aquatic environments capable of supporting them were conducted on a trial and error basis by stocking. White perch were no exception.

Fuller and Cooper (1946) summarized the fact that fish-culture enterprises by Federal and State hatcheries made possible the heyday of stocking white perch in Maine between 1880 and 1910. As early as 1871 distribution by the United States Fish Commission extended the range of this species to many new waters within Maryland (Bowers 1905), Connecticut (Bowers 1913), and New York (Titcomb 1905). Bowers (1913) reported a total of 442,177,500 white perch eggs and fry distributed to various states in 1911, including Connecticut and Massachusetts. Baird (1884) stated fry were stocked in Quantico Creek, Maryland in 1882. Mather (1889) reported specimens shipped to Germany twice in 1886 and once in 1887. Only the latter shipment survived which consisted of three specimens 127 to 152 mm in length. Annual reports of the New York State Conservation Department of Inland Waters between 1933 to 1939 state white perch fingerlings and adults were commonly introduced into many waters within that state. Thorpe (1942) also indicated that this species was stocked in Connecticut Lakes from 1930 through 1939. Between 1875 and 1936 Maryland waters received several billion white perch fry (Mansueti and Mansueti 1955). Chesapeake Bay, noted for large populations of white perch, likewise was stocked in many years with several million artificially hatched white perch fry (*Bigelow* and *Schroeder* 1953).

Once introduced into inland waters it was only a matter of time before this species expanded its range into Ontario (Scott 1963), Quebec (Vladykov 1952) and Lake Erie (Larson 1954, Bush et al. 1977). In 1963, Scott and Christie reported the northernmost known white perch population on the Atlantic coast as the Miramichi River, New Brunswick. Bean (1885) and Dence (1952) describe the expansion of white perch in the state of New York. Recent surveys of anadromous fish spawning areas by O'Dell et al. (1975) discovered white perch to be the dominate species in the Upper Chesapeake Bay Area. It was documented in 135 streams and rivers, many of which were used for spawning and nursery functions; these waters included the Elk, Lower Susquehanna, Bush, Gunpowder, and Patapsco rivers, and the west Chesapeake Bay and Chesapeake Bay proper. Baughman (1943) reported an unknown number of white perch collected in Texas and forwarded to the Smithsonian Institution where they were subsequently identified by Mr. Earl D. Reid. No specifics were alluded to on how they arrived there.

Besides the Canadian Maritime Province region, a letter questionnaire of knowledgeable fisheries personnel in private, state, and federal institutions by this author indicated that white perch are present in 36% of all states as of 1978. Those states where populations exist include: Connecticut, Delaware, Indiana, Maine, Maryland, Massachusetts, Michigan, Nebraska, New Hampshire, New Jersey, New York, North Carolina, Ohio, Pennsylvania, Rhode Island, South Carolina, Vermont, and Virginia.

White perch were introduced into Nebraska waters in 1964 (Hergenrader and Bliss 1971), and currently their distribution could very well allow them to be dispersed into waters of adjacent states in the Midwest Region (Hergenrader 1980). In addition to the distribution of white perch presented by Hergenrader (1980), this species has been documented recently in other nearby lentic environments in the general vicinity of Salt Creek and the Platte and Missouri Rivers. Fisheries biologists of the Nebraska Game and Parks Commission discovered white perch in Offutt Air Force Base Lake located in Sarpy County during the summer of 1978. A resident population of age I and II fish were sampled using three trap nets set overnight. Results showed that of 321 fish representing 12 species sampled, 57% were white perch. This 65 hectare lake is adjacent to the Missouri River and was most likely invaded by white perch during high spring flows in recent years. Ridgewood Lake, another sandpit situated near Fremont, was also found to contain white perch. Three specimens ranging from 239-244mm TL were sampled by Commission biologists on August 27, 1980. The most notable discovery, of white perch in Nebraska involved one specimen captured by Commission fisheries research personnel in Pawnee Lake on May 23, 1980. This white perch was a ripe male weighing 405 grams and had attained a total length of 290 mm. When aged it proved to be a five year old specimen. That a white perch was sampled in Pawnee is somewhat alarming in view of the fact that the lake is located in the same watershed as Wagon Train and Stagecoach Lakes. As long as remnant populations of white perch remain in standing bodies of water connected to adjacent to or subject to periodic flooding by Nebraska streams, the threat of reinvasion by white perch into larger lakes and reservoirs will remain.

Whether or not white perch are effectively utilized as a resource by commercial or sportfishing interests depends to a large degree on the quality and location of that resource. Previous stockings have benefited the commercial fishery for white perch stocks along the Atlantic coast. Various fishery statistics compiled by the Fish and Wildlife Service of the United States Department of the Interior bear this out (Fiedler 1939, Anderson and Power 1953). Data presented shows the commercial catch of white perch in thousands of pounds and thousands of dollars for the New England and Middle Atlantic States, Chesapeake Bay, and the South Atlantic States. Maltezos et al. (1975) studied the size and age distribution of the white perch population in the Lower Connecticut River where stocks were sufficient to warrant commercial gill net fishing. Results showed that utilization of this gear type during the months of December through March had no apparent effect on the size distribution of the population in 1972 through 1974. Commercial catches in the Middle Atlantic region (New Jersey – North Carolina) exceeded the catch from the North Atlantic region (Maine – New York) between 1960 and 1975 (McHugh 1977). During this time span the catch from the Middle Atlantic region ranged from 500 to 1,366 metric tons, while the North Atlantic region yielded lesser amounts ranging from 10 to 98 metric tons. Coffey (1978) provided pertinent commercial statistics on total weights of white perch harvested and these values in New York, New Jersey, Delaware, Maryland, and Virginia in 1976 and 1977.

Utilization of white perch populations for sportfishing purposes has occurred in many waters throughout its native range of the Atlantic coast. Abbott (1871) mentions fishing for them in the Delaware River in the vicinity of Trenton, New Jersey. Trippensee (1953) contended white perch along the Atlantic Coast held approximately the same economic status as yellow perch, *Perca flavescens* (Mitchill) do further inland. Kearson (1969) tagged resident fishes including white perch in the Chowan River of North Carolina and Virginia and stated that white perch were held in high esteem by sport and commercial fishermen. Tag returns from this study indicated either downstream movement or movement into a tributary. One specimen traveled 104 km downstream from the point of capture through a portion of Albemarle Sound and was later recaptured near the mouth of the Perquimans River. In the Potomac Estuary still fishing yielded more white perch than trolling (Frisbie et al. 1963) whereas in Lake Waccamaw, North Carolina trolling with silversides, *Menidias extensa,* was the common method to harvest white perch (Davis and Louder 1969). King (1947) estimated 36,000 white perch taken by pole and line fishing in Lake Mattamuskeet, North Carolina in 1945. This species was also the second most abundant fish in the sportfishing harvest of the Susquehanna River (Whitney 1961). Discharging warm water along a one-mile canal from the Potomac Electric Power Company on the Patuexent River, Maryland created a winter sport fishery where white perch dominated the catch from January through April, 1970. An estimated 49,009 fish (84%) out of a total of 58,453 fish representing 9 different species caught were white perch (Moore and Frisbie 1972).

A similiar survey was conducted from May 1971 through April 1972 within the Patuxent Estuary and the effluent canal of the Potomac Electric Power Companys steam electric plant at Chalk Paint, Maryland. Results showed that out of 8 species harvested, 383,900 specimens, white perch made up 49% of the total number harvested. Interestingly, 85,300 (45%) of all white perch caught were returned to the water (Moore et al. 1973). The heated discharge of the Connecticut Yankee Power Company nuclear power plant also provided a winter-spring sport fishery where white perch, white catfish, *Ictalurus catus* (L.) and brown bullheads, *Ictalurus nebulosus* (Lesueur) constituted 75% of the total catch. White perch made up 32% (3608) of 11,090 fish representing 18 species (March and Galvin 1973). Between 1954 and 1958 white perch, yellow perch, and brown bullheads made up 70% of the angling catch in Quabbin Reservoir, Massachusetts (McCaig and Mullen 1960). White perch also composed the majority of fish counted during a 1971 survey of fishermen in South Branch Lake, Maine. However, Bryant (1972) commented that this species is not highly prized in Maine. McHugh (1977) estimated recreational catches of white perch in the North and Middle Atlantic regions. In the northern region (Maine – New York) the catch between 1960 and 1975 ranged from 15 to 386 metric tons (33,069 – 850,975 pounds). In the same time period the catch for the Middle Atlantic region (New Jersey – North Carolina) ranged from 2,984 to 5,712 metric tons (6,578,526 – 12,592,675 pounds).

One of the most influential water quality characteristics important to fish is temperature. Among others, it is this factor which regulates metabolism and the ability of fish to survive and reproduce successfully. Temperature influence literature is voluminous but is greatly adding to the ability of man to apprehend and mitigate his actions on the environment (Hutchinson 1976, Coutant 1977, Brugs and Jones 1977). Using Patuxent estuary white perch in the laboratory, McErlean (1969) tried to demonstrate thyroidal influence on temperature tolerance. Although temperature tolerance was not found to be dependent upon thyroidal state, it was highly correlated with seasonal acclimation state (seasonal adaptation), being proportionately greatest during colder months and least during warm ones. White perch were found to exhibit tolerances intermediate between salmonid and cyprinid fishes.

Working with oxygen concentrations and increased temperatures Dorfman (1970) experimented in the laboratory with white perch captured from the Delaware River near Philadelphia. Those exposed to daily diurnal fluctuations of oxygen averaging 3.0 mg/liter (range 1.0 - 6.6) appeared to grow slower than those maintained at oxygen concentrations of 7.0 mg/liter (range 3.7 - 8.5). All perch subjected to daily temperature increases (averaging - 14.2°C) were dead at 34°C. White perch acclimated to 18.3 and 26.6°C, and then exposed to rapidly rising temperatures, lost equilibrium at 34°C and 35.5°C respectively. Meldrim and Gift (1971) stated that it is well established that acclimation in fishes is more rapid to temperature increases than to decreases in temperature. Using a variety of sizes of white perch the above authors determined the preferred temperature from November, 1969 through November 1971. Acclimated temperatures ranged from 1.1 to 30°C (34-86°F). Preferred temperatures ranged from 5-32.2°C (41-90°F) and were usually equal to or higher than the ambient acclimation temperatures.

Using white perch 65-74 mm TL the maximum preferred temperature was 32.2°C (90°F) when ambient acclimation was 23.9°C (75°F) in mid-July and 31.1°C (88°F) when ambient acclimation was 30°C (86°F) in mid-August. Minimum preferred temperatures for 181-208 mm TL perch was 5°C (41°F) when ambient acclimation was 1.1°C (34°F) and 1.6°C (35°F) in February. Meldrim and Gift concluded white perch actively avoid stressful thermal conditions but the temperature which elicits avoidance response is dependent on acclimation temperature, light level, salinity and size of fish affected by temperature increase. Gift and Westman (1971) studied various species of estuarine fish, including white perch. In replicate studies the mean avoidance temperature of 32°C was determined with white perch (mean lengths of 122 and 169 mm TL). For most estuarine species water temperatures above 30.5°C were deemed unacceptable. McErlean and Brinkley (1971) used one year old Patuxent estuary white perch to test the seasonal temperature tolerance of white perch. Calculated LD_{50} values were as follows:

Date	Collection Temp., °C	Acclimation Temp., °C	LD_{50}
Oct. 6, 67	22.7	27.8	32.7
Nov. 11, 67	6.5	17.5	27.7
Dec. 7, 67	3.8	10.4	27.2
March 28, 68	2.9	10.0	26.2
June 5, 68	23.4	20.3	29.2
Sept. 9, 68	24.5	28.5	33.2
Nov. 13, 69	12.0	10.0	26.0
Dec. 16, 69	6.5	10.0	23.6

Meldrim and Petrosky (1974) working with Delaware estuary white perch appropriately stated that in order to determine the limits of ecological alternation, the limits of habitable conditions for affected species must be known. This comment was related to the increased use of estuarine waters for cooling purposes by steam electric power stations. Behaviorial avoidance responses to temperature and chlorine were determined under various conditions of salinity, light level, and level of dissolved oxygen over the annual range of temperatures normally found in the estuary. Physiological responses in terms of metabolic rate and scope for activity were also determined for different levels of salinity over the same annual range of temperatures. Analysis of test data using a linear multiple regression model with interactions reduced estimated avoidance temperatures under significant modifying factors. Results showed that test or acclimation (field) temperature was undoubtedly the dominant factor effecting behavioral or physiological response. Extensive results were presented and this paper should be reviewed for further details.

Temperature preference tests were also conducted on freshwater white perch collected from Albemarle Sound, North Carolina; Wicomico River, Maryland; and Mullica River, New Jersey. Collection temperature was 55° C and acclimation temperatures used in the tests were 6, 12, 18, 24, 30, and 33°C. Calculated final temperature preferences using linear regression for North Carolina, Maryland, and New Jersey populations of white perch were 32.4, 28.9, and 29.6°C respectively. Using a quadratic equation, the calculated final temperature preferenda were 31.6, 29.3, and 29.2°C respectively. When visual interpretion was made the above values for the respective states were estimated to be 33.5, 30.6, and 29.6°C (Hall et al. 1978). Citing Holsapple and Foster (1975), Meldrim and Petrisky (1974), and Sheri and Power (1968), Brugs and Jones (1977) in EPA's protocol and procedures for freshwater fish give the preferred temperature of juvenile white perch acclimated at 6, 15, 20, 26-30°C, as 10, 20, 25, and 31-32°C respectively. Spawning temperatures ranged from 11-20°C in May and June. Maximum weekly average temperature for spawning was 15°C; maximum temperature for embryo survival was 20°C.

With the advent of nuclear power plants and their water requirements for cooling purposes, temperature as it pertains to aquatic forms of life has continued to be an environmental concern. Marcy (1973) studied the vulnerability and survival of young Connecticut River fish entrained at the Connecticut Yankee nuclear power plant during June and July. Young fish of nine species, including white perch were dead by the time they reached the lower end of the plants 1.83 km (1.1 mile) discharge canal. Water temperaure of the canal was 30^{o}C approximately 95% of the time. Further analysis showed that approximately 80% of the mortality in the canal was caused by mechanical damage and 20% was attributed to heat shock and prolonged exposure to water temperatures elevated above 28^{o}C.

Hybridization of white perch is increasingly being looked upon as a possible way to obtain a biologically acceptable species which would be sought after by anglers. To date, however, results have not been very promising. White perch males were first crossed with white bass females to obtain a hybrid (Ryder 1887). Smith et al. (1966) reported a male white perch crossed with female striped bass female was a biological first which produced 80,000 hybrid fry. In an effort to develop hybrids which might be more adaptable to North Carolina reservoirs instead of striped bass with its specialized spawning requirements, Phillips (1967) worked with fry crosses between male white bass *Roccus chrysaps* (Rafinesque) and male white perch *Roccus americanus* with female striped bass. Problems of mortality were experienced with the fry but some observations were obtained. For example, white perch x striped bass fry hybrids tended to congregate near the surface and along the sides of aquariums. In contrast, when fry were siphoned inadvertantly into a plastic bucket while cleaning aquaria, they remained near the bottom. Other fish typically collected near the surface. Bayless (1972) worked on distinguishing larvae hybrids produced from crossing white perch males with striped bass females. He found that these hybrids could be separated by a 1 mm wide area containing heavy pigmentation covering the entire dorso-ventral axis, and located posterior to the anus. Kerby and Joseph (1979) also studied meristic characters of hybrids produced from female striped bass and male white perch. Kerby and Joseph (1979) also reported that the above hybrid increased in weight at a more rapid rate/unit length than did striped bass but at a less rapid rate than did white perch.

Generally speaking the white perch is an acceptable game fish to the angler and commercial fisherman in waters it inhabits, provided it reaches a total length of approximately 203 mm. What normally happens is that a population becomes over abundant due to its prolific reproductive capabilities, resulting in a population of smaller, less desirable specimens. This places added burdens on fisheries personnel whose responsibilities are to manage waters containing this species. Additional literature is quite voluminous and will not be covered here; instead appropriate references will be cited throughout the text on the various aspects of the biology of the white perch.

METHODS AND MATERIALS

Collecting and Sampling Procedures

Fisheries personnel of the Nebraska Game and Parks Commission have conducted inventories of the fish populations in Wagon Train and Stagecoach reservoirs since 1965. Experimental gill nets, 45.7 meters long and containing 7.6 meter panels of mesh of 1.9, 2.5, 3.8, 5.1, 6.4 and 7.6 cm square mesh were used to sample the bottom areas of the reservoirs, while trap nets with 1.3 cm bar mesh were used in the shoreline areas. Each reservoir was also electrofished during each survey for one to two hours using a 230 volt A.C. (10.9 amp.) portable generator.

Age and Growth

Age and growth of white perch in both reservoirs was determined from scales collected from 993 yearling-plus specimens. The majority of white perch were captured in standard surveys in August although scales from white perch sacrificed for food habit data before and after the month of August were also included for age and growth analysis.

At certain times of the year experimental gill nets were the only gear effective in adequately sampling white perch. An otter trawl was tried but proved to be unreliable in capturing white perch, due mostly to mechanical problems. A 7.3 meter bag seine with 0.6 cm mesh was used occasionally to capture young-of-the-year fish in order to ascertain species composition along the shore of Stagecoach.

All pertinent measurements were taken in the field. Fish lengths (total length) were measured to the nearest millimeter. Fish were weighed to the nearest gram on a Pelouze 1000 gram dietetic scale or a Chatillon portable scale accurate to 0.1 pound (0.0454 kilograms).

Scales used to determine the age of white perch were taken from the area above the lateral line and below the spinous and soft dorsal fin. According to Mansueti (1960), scales from this area are the most reliable for use in age and growth studies. Six to 10 scales from each fish were impressed on a single slide of cellulose acetate with a Wildco model 110 scale press. Scale images were magnified 40 times with an Eberbach scale micro-projector. Projected images of white perch scales were measured from the focus to the lateral margin with the distance from the focus to each annulus and the scale edge being recorded. In the instances when a fish was captured after January 1 but prior to annulus formation, the specimens were assumed to have an annulus on the outer lateral margin. Because of the fast growth exhibited by Nebraska white perch, scales of this species were easy to read. Generally "crossing over" and crowding of the circuli were adequate to detect year marks. Mansueti (1961) also found this to be true.

In order to determine time of annulus formation scales from 510 Stagecoach white perch, ages I-III, were examined from March through July in 1973 and 1974.

Mortality and survival rates of white perch were estimated using the difference in logarithm values between age classes captured in gill nets (Ricker 1975).

The length-weight relationship of white perch was calculated from 2370 Stagecoach white perch ranging in size from 30-279 millimeters total length. The equation to determine this relationship was that of Ricker (1975) where $w = al^b$.

In backcalculating growth, scale length versus total fish length was plotted using a linear regression program on an IBM 2741 computer. A correction factor (y intercept) was calculated.

Reproduction

Spawning Season

To establish the spawning period of white perch, observations of the gonads at frequent intervals were carried out during the spring months of 1973 and 1974. Reference to gonad development stages correspond to those given by Mansueti (1961) and Miller (1963). For females, this entailed observing the development changes of the ovaries as immature, mature developing, mature-gravid and mature-spent. Immature, mature-latent, mature-ripe, and mature-spent were used to differentiate the stages of testes development. Following the spawning season, spent white perch, expecially older fish, could be distinguished because of their lean appearance and sunken abdomens as well as by the appearance of the gonads.

The eggs of two mature females were used to estimate the mean diameter of unfertilized eggs in the ovary. Two groups of eggs distinct according to size were observed in all parts of the ovary. Both sizes of eggs were measured in this determination, and a sample of 24 eggs was measured from each of two fish, one a 167 mm TL, 65 gram, age group I and the other a 256 mm TL, 234 gram, age III specimen. The egg diameters were measured under a dissecting microscope equipped with a calibrated micrometer. The slightly moist eggs were placed in a petri dish and gently teased apart. The mean diameter and range of each sample of eggs from each ovary was determined.

Fecundity

Females used for fecundity determinations were collected in May and June, 1973. Upon extraction in the field, each pair of ovaries was wrapped in cheesecloth and placed in a labelled glass jar containing a 10% formalin solution. In the laboratory, the ovaries were weighed to the nearest milligram on a Sartorius balance after they were blotted dry. Fecundity was estimated by a modification of Lehman's (1953) method. Two subsamples with eggs from the anterior, central, and posterior regions of each ovary were extracted. Four hundred eggs from each subsample were gently teased apart in a petri dish with the aid of a dissecting microscope. Each sample of 400 eggs was then weighed and the remaining membrane separated from the rest of the ovary. By direct proportion of egg weights, the total number of eggs in each ovary was calculated. Regression analysis was run on the Wagon Train fecundity data using an IBM 360/65 computer.

Sex Ratio

The sex ratio of white perch was determined by examining the reproductive organs of 976 individuals representative of all age groups, collected in Stagecoach reservoir surveys in 1973 and 1974.

Food Habits

In order to evaluate the food habits of white perch, black crappie, and largemouth bass in Stagecoach reservoir, stomachs were collected twice each month during the growing season of 1973 and 1974. If possible, 10 fish of each species were collected each sampling period with gill nets and/or electrofishing gear. Upon capture, each specimen was measured, weighed, sexed, and then sacrified to obtain its stomach. All specimens were sacrificed in the field rather than preserve the whole specimen in order to prevent regurgitation of food items (Turner 1955). The individual stomachs were subsequently preserved in a 10% formalin solution for analysis at a later date in the laboratory.

Stomach contents were placed in a petri dish and examined under a binocular dissecting microscope. Identification of food items was conducted using Ross (1944), Pennak (1953), Borror and Delong (1964), Johannsen (1969), and Usinger (1971). In this study, the following data were recorded:

(1) The frequency of occurrence of each food item.

(2) The identification and number of each food item in each stomach. Most items were individually counted and tallied on a hand counter. However, numbers of zooplankton in stomachs were estimated by averaging the number of plankters in 4-6 aliquots counted in a Sedgwick-Rafter cell (Serfling 1949; Kutkuhn 1958), and by direct proportion to a known volume of concentrate (50 ml), calculating the number present.

(3) Each food item group was consolidated on a monthly basis and a total volume determined in a graduated cylinder. Similar food items were pooled, particularly when dealing with small organisms, because of their size and various states of digestion.

(4) The total dry weight of each food group item condensed on a monthly basis. Large items such as fish and crayfish were individually dried and their weights summed. Drying was done in a Lab-Line Instrument oven. Large items such as crayfish and fish were dried to a constant weight at a temperature of 100°C. Normally this took 4 to 7 days. Insects were dried for a 24 hour period at 70°C (Gerking 1962; Tebo 1955).

To facilitate comparisons between the four methods used, only the percentage values are reported.

Population Inventories

In order to assess white perch populations, survey data collected in 1973, 1974, and 1975 in Stagecoach reservoir and 1974 in Wagon Train reservoir was summarized. Experimental gill nets, trap nets, and electrofishing gear were used in these collections. Data obtained in population inventories in both reservoirs prior to 1973 were also included in order to assess white perch population trends.

RESULTS AND DISCUSSION

Age and Growth

In order to understand the biology of a fish species, knowledge of growth characteristics of the population is necessary. To establish the body length-scale length relationship of the white perch, scales from Stagecoach Reservoir specimens were utilized. Projected scale measurements were grouped according to the total length of the fish from which they were taken. Mean values were calculated for the total length and projected scale radius of each 10 millimeter size group. From these data a linear regression was run and found to best fit a second degree polynomial (Zuerlein 1975). The point on the length axis which gives the best fit ("a") to the body-scale curve was calculated to be 21.4 mm TL.

For all age groups combined (I-III) annulus formation of white perch in Stagecoach reservoir occurred in the months of April through July (Table 1). In Sebasticook Lake, Maine annulus formation occurred from the 3rd week in June to the 2nd week in July (AuClair 1956). Conover (1958) reported that it occurred the latter part of March in Albermarle Sound and the Lower Roanoke River, North Carolina. In the Patuxent Estuary annulus formation occurred during April, May, and June (Mansueti 1961). Miller (1963) observed similar results in the Delaware River Estuary. Sheri and Powers (1969) noted the peak period of annulus formation on the scales of white perch inhabiting the Bay of Quinte in July while Wallace (1971), working on the Delaware River, reported that annulus formation for all ages combined, occurred from the first week in May to late August, but that most white perch had completed the annulus by mid-June.

Growth rates of fish are dependent upon environmental conditions within a body of water. In Wagon Train reservoir white perch reached a total length of approximately 109 millimeters by age I (Table 2). The largest annual length increment occurred between ages 0 and 1. Growth continued in each successive year but the annual length increment decreased remarkably after age II.

In Stagecoach reservoir white perch reached a total length of approximately 128 millimeters by age I (Table 3). As in Wagon Train reservoir the first annual increment was also the largest. Likewise, growth to age II and III was comparable to that achieved by this species in Wagon Train reservoir, but in Stagecoach reservoir the annual length increment decreased drastically after age II.

Compared to the growth achieved by white perch in its native range, growth in Nebraska was very rapid except in Buckley 3F (Table 4). Along the East coast, white perch reach an average total length of 170-282 millimeters in four to seven years (Hueske 1948; McCaig and Mullen 1960; Saila and Horton 1957; Conover 1958; Mansueti 1961; Miller 1963; Richards 1960). Nebraska white perch, however, reach 178 millimeters by their second annulus with some individuals reaching 229 millimeters at the time of the third annulus. Buckley 3F white perch were the exception though with growth rates for age I and II individuals approximating that achieved by this species in eastern parts of its range (Table 4). In Wagon Train reservoir few individuals lived to be four years old. Only two white perch have ever been documented to be five years old in Nebraska. The first specimen was collected in Wagon Train reservoir prior to the spring spawning season in 1973 and had reached a total length of 318 millimeters and a weight of 0.54 kilograms. The second specimen was collected in Pawnee reservoir in May, 1980. It was 290mm TL and weighed 0.41 kilograms. Normally, fast growth is associated with high quality sport fisheries. However, this was not the case with white perch in Nebraska.

Table 1. Annulus formation of 510 white perch of age group I-III in Stagecoach reservoir on a monthly basis in 1973 and 1974.

	March	April	May	June	July
		1973			
Annulus Completed	––	6 (100%)	159 (63.9%)	22 (84.6%)	11 (100%)
Annulus not Completed	––	0	90 (36.1%)	4 (15.4%)	0
Totals	––	6	249	26	11
		1974			
Annulus Completed	0	0	5 (9.8%)	26 (56.5%)	26 (92.9%)
Annulus not Completed	44 (100%)	49 (100%)	46 (90.2%)	20 (45.5%)	2 (7.1%)
Totals	44	49	51	46	28

Table 2. Backcalculated growth of 103 white perch captured in 1972 and 1974 from Wagon Train Reservoir, Nebraska.

Year Class	N	Mean Total Length At Capture	Mean Total Length At Formation Of Annulus I	II	III	IV
1973	15	170	102			
1972	19	229	114	198		
1971	15	224	114	201	254	
1970	22	226	104	158	231	274
1969	17	236	107	165	208	–
1968	15	295	112	178	231	274
Grand average calculated length in millimeters			109	178	229	274
Grand average calculated length in inches			4.3	7.0	9.0	10.8
Average increment in millimeters			109	66	48	43
Average increment in inches			4.3	2.6	1.9	1.7

Table 3. Backcalculated growth of 890 white perch captured in 1972, 1973, and 1974 from Stagecoach Reservoir, Nebraska.

Year Class	N	Mean Total Length At Capture	Mean Total Length At Formation Of Annulus I	II	III	IV
1973	181	149	114			
1972	295	173	121	189		
1971	398	222	139	208	232	
1970	16	210	129	198	–	
Grand average calculated length in millimeters			128	203	232	
Grand average calculated length in inches			5.03	7.9	9.1	
Average increment in millimeter			128	68	24	
Average increment in inches			5.03	2.7	.9	

Table 4. Comparison of white perch growth in Nebraska and other states.

Location	Average TL in mm at Annulus 1	2	3	4	5	6	7	8	9	10	12
1. New York	91	142	168	170	216	208	241	216	246	241	277
2. N. Carolina	–	–	165	196	241	274	–	–	–	–	–
3. Massachusetts	109	165	213	246	–	–	–	–	–	–	–
4. Massachusetts	84	150	198	226	239	–	–	–	–	–	–
5. Massachusetts	91	155	206	234	254	269	282	305	320	330	–
6. Rhode Island	99	165	208	236	246	269	282	290	–	–	–
7. Nebraska	109	178	229	274	–	–	–	–	–	–	–
8. Nebraska	127	200	231	–	–	–	–	–	–	–	–
9. Nebraska	102	150	–	–	–	–	–	–	–	–	–
10. N. Carolina	74	112	150	183	211	234	254	272	–	–	–
11. Maryland	94	142	170	188	206	226	246	262	277	302	–
12. Delaware	94	147	173	191	208	226	239	254	307	320	–

Reference:

1. Richards 1960, Cross Lake
2. Hueske 1948, Bay Lakes
3. McCraig and Mullen 1959, Quabbin Reservoir 1942-46
4. McCraig and Mullen 1959, Quabbin Reservoir 1953-57
5. Taub 1966, Quabbin Reservoir 1964-65
6. Saila and Horton 1957, Rhode Island Lakes
7. Zuerlein 1975, Wagon Train Reservoir
8. Zuerlein 1975, Stagecoach Reservoir
9. Lund 1978a, Buckley 3F Reservoir
10. Conover 1958, Albemorle Sound and lower Roanoke River (Estuary)
11. Mansueti 1961, Patuxent Estuary
12. Miller 1963, Delaware River Estuary

Table 5. Length frequency distribution of white perch collected with 8 gill nets from Wagon Train reservoir, 1972 & 1974.

Millimeter Class	25	51	76	102	127	152	178	203	229	254	279	305
Inch Class	1	2	3	4	5	6	7	8	9	10	11	12
Frequency of occurrence, 1972	0	0	0	274	199	40	8	11	4	3	3	2
Frequency of occurrence, 1974	0	0	0	0	203	337	23	36	18	9	11	5

Table 6. Length frequency distribution of white perch collected with 8 gill nets from Stagecoach Reservoir, 1973 & 1974.

Millimeter Class	25	51	76	102	127	152	178	203	229	254	279	305
Inch Class	1	2	3	4	5	6	7	8	9	10	11	12
Frequency of occurrence, 1973	0	0	0	0	29	46	20	122	139	0	0	0
Frequency of occurrence, 1974	0	0	1	1	100	336	173	87	144	9	0	0

There was pronounced natural mortality after age II (177-254 mm) with very few white perch living to be more than three years old in Wagon Train reservoir (Table 5). The Stagecoach population (Table 6) had a larger number of individuals which reached age II (228-254 mm) but the trend of the population structure appeared to be following that of Wagon Train. Because the white perch populations in both reservoirs experienced a high natural mortality by the end of their third year of growth, few acceptable size white perch were available. The result was that white perch were not utilized for the most part by Nebraska anglers.

Mortality Rates

Estimation of survival rates and mortality rates from age composition of white perch which were expanding in numbers in Stagecoach reservoir are given in Table 7. As presented in the population inventory section of this report white perch were believed to have entered and spawned in Stagecoach reservoir in 1970. A perch year class of this particular year existed based on scale analysis. This means that it would of been 1973 before any individuals could have attained an age of four years. Survey results in 1973 and 1974 showed that no age four white perch were ever sampled, indicating a high annual rate of mortality especially for older fish. Annual mortality estimates between age II and age III fish in 1972, 1973, and 1974 varied but by 1974 the annual mortality was calculated to be .400 (Table 7). Combining the above three years data showed a high survival rate, between age I and II but between age II and III it started to decline.

Table 7. Instantaneous (Z); annual (A); mortality rates and survival of white perch captured from Stagecoach Reservoir in 1972, 1973, 1974.

Age Class	Percentage Composition	Log_e	Z	A	S
		1972			
II	67	4.205			
			.986	.627	.373
III	25	3.219			
		1973			
II	39	3.664			
			.138	.129	.871
III	34	3.526			
		1974			
II	30	3.401			
			.511	.400	.560
III	18	2.890			

Instantaneous (Z); annual (A); mortality rates and survival (S) of white perch captured in Stagecoach Reservoir in 1972, 1973, and 1974 combined.

Age Class	Percentage Composition	Log_e	Z	A	S
I	41	3.714			
			.130	.122	.878
II	36	3.584			
			.449	.362	.638
III	23	3.135			

White perch were present in Wagontrain reservoir from 1964 to 1975 yet only one specimen was ever collected and aged to be 5 years old. Survival of age classes normally fluctuate to some degree in aquatic environments. Using 1974 data highest annual mortality rates were calculated between age I and II but then declined between age II and III and between age III and IV (Table 8). The fact that no fish over age IV were sampled indicates that annual mortality past four years must approach 1.00.

Table 8. Instantaneous (Z); annual (A); mortality rates and survival of white perch captured from Wagon Train Reservoir in 1974.

Age Class	Percentage Composition	Log_e	Z	A	S
I	82	4.407			
			2.009	.866	.134
II	11	2.398			
			1.012	.637	.363
III	4	1.386			
			.693	.500	.500
IV	2	.693			

Length-Weight Relationship

Knowledge of length-weight relationships of fish are of great value in fisheries management. When this relationship for a particular species of fish in a certain area has been determined, it can be utilized to calculate weights of fish when only their lengths are known, and vice-versa. Also, coefficients of condition (KTL) can be derived from length-weight data allowing comparison of condition factors for species of fish in different bodies of water.

The length-weight relationship was calculated using FIRE 1, a computer program run on an IBM 360/65 (Hesse 1977). Initially separate relationships for 1973 and 1974 data were computed (Table 9) and mean KTL's and predicted weights arrived at for various total length intervals. Mean TKL by sex is also presented in the above table for each year. The separate data of 1973 and 1974 were combined to calculate an overall length weight relationship. A total of 2370 white perch, collected from Stagecoach reservoir, and ranging in size from 60-279 mm total length constituted the data base. The correlation coefficient of the length-weight relationship was 0.96. The equation used to determine the length-weight relationship was $W = aL^b$ where W equals weight, a equals the Y intercept, L is total length of fish, and b is the slope of the regression line. If one or the other is known, the weight or length of a white perch can be determined using the computed substituted values as follows:

W = weight in grams
a = Y intercept of $10^{-4.594}$
L = total length in mm
b = slope of 2.89

Expressed logarithmically (Table 10) the above formula becomes

$$\log W = \log a + b \log L$$

or

$$\log W = -4.594 + 2.89 \log L$$

Table 9. Predicted weights (using the regression coefficients), and mean condition factors (KTL) by length interval and by sex for white perch collected in Stagecoach reservoir.

Class Interval (MM)	1973 Fish (N)	1973 Pred. Wts. (GMS)	1973 Mean KTL	1974 Fish (N)	1974 Pred. Wts. (GMS)	1974 Mean KTL
1 – 20	0	0.21	0.0	0	0.14	0.0
21 – 40	0	1.41	0.0	0	1.07	0.0
41 – 60	0	4.30	0.0	0	3.47	0.0
61 – 80	0	9.49	0.0	6	8.02	0.86
81 – 100	0	17.54	0.0	23	15.35	1.46
101 – 120	6	28.97	2.86	33	26.09	1.74
121 – 140	17	44.29	2.92	72	40.86	1.75
141 – 160	67	63.97	1.47	355	60.26	1.59
161 – 180	53	88.47	1.41	371	84.89	1.45
181 – 200	56	118.25	1.39	265	115.33	1.50
201 – 220	145	153.73	1.48	129	152.19	1.44
221 – 240	301	195.35	1.46	255	196.03	1.40
241 – 260	57	243.51	1.45	147	247.43	1.40
261 – 280	1	298.62	1.43	10	306.97	1.30
TOTALS	703			1666		

1973: $\text{Log } W = -4.2625 + 2.75 \text{ Log } L$

1974: $\text{Log } W = 4.6324 + 2.91 \text{ Log } L$

	1973 Male	1973 Female	1974 Male	1974 Female
Mean KTL	1.4684	1.5167	1.4600	1.5236
Standard Deviation	0.2711	0.6295	0.3153	0.6201
Coefficient of Variation	18.4619	41.5024	21.5985	40.6972
Standard Error	0.0138	0.0370	00.0143	0.0300
Mean Square	0.0735	0.3962	0.0994	0.3845
Degrees of Freedom	382	288	487	425

Table 10. Condition factors (KTL) by month and by sex for white perch collected from Stagecoach reservoir in 1973 and 1974 combined.

Month	Mean KTL	Std. Dev.	N
March	1.289	0.219	45
April	1.585	0.145	51
May	1.497	0.172	262
June	1.469	0.207	64
July	1.514	0.125	31
August	1.438	0.131	1774
September	1.514	0.123	49
October	1.485	0.125	76
November	1.466	0.112	18
Total	1.450	0.145	(2370)

Log W = -4.594 + 2.89 Log L

	Male	Female
Mean KTL	1.4637	1.5208
Standard Deviation	0.2966	0.6235
Coefficient of Variation	20.2608	40.9949
Standard Error	0.0100	0.0233
Mean Square	0.0879	0.3887
Degrees of Freedom	871	715

Condition Factors

The coefficients of condition (KTL) or degree of well being of white perch was calculated using the data base utilized in computing the length-weight relationship. The equation used was $KTL = 10^5W / L^3$ (Hile 1936). KTL values for 1973 fish in the 101-140 mm range appear to be high and most likely can be attributed to sampling procedures and/or equipment when these fish were collected (Table 9). A one way analysis of variance and a Duncans Multiple Range test were run on KTL's. No apparent trends of biological significance were noted, consequently mean KTL's are presented by length interval (Table 9) and month (Table 10).

Reproduction

Spawning Season

White perch school in most bodies of water they inhabit (Thoits 1958). Throughout most of the Nebraska study white perch were easily sampled in shallow water toward dusk with an electroshocker. Normally daylight shocking was not effective in capturing white perch. Presumably this movement of white perch into the shallows in the evening was to feed on benthic organisms. Webster (1942) also noted this shoreward movement in Bantam Lake, Connecticut as did Richards (1960) in Cross Lake, New York. During the spawning season white perch concentrated in shallow areas and could be electroshocked during the day as well as at night. After the spawning season these concentrations of fish moved to deeper water, at which time a gill net was necessary to collect them, especially the larger and older individuals.

Electrofishing Stagecoach reservoir during mid morning of May 8, 1973 yielded large numbers of males in the mature-ripe and five females in the mature-gravid condition off the dam along the east shore. These fish ranged in size from 107 mm to 244 mm total length. Water temperature then was 14.4°C. The next day the reservoir temperature rose to 19.4°C and numerous mature white perch of both sexes were again collected with the same sampling gear. On May 11, 1973 a situation similar to May 8 and 9 was encountered as numerous mature male and female white perch, ranging from 102 mm to 239 mm total length, were collected and examined. Water temperature however, had dropped to 17.7°C. On May 15, 1973, with the reservoir temperature still at 17.7°C, numerous white perch of both sexes were electroshocked after dark. Examination of their gonads revealed them to be mature, almost spawning ripe. By June 6, 1973 the water temperature had increased to 21°C. Females collected then had ovaries in the mature-spent condition while most male testes were mature-spent. Electro shocking in the shallows of Stagecoach reservoir produced no large concentrations of white perch on the afternoon of June 7, 1973. Based on these observations, it was concluded that white perch spawned sometime during the last two weeks of May or the first week in June. Nine males and two females were captured on June 21, 1973 which distinctly showed sunken abdomens. Closer examination revealed that the testes yielded little milt and the ovaries retained only a few ova. However, on July 5, 1973 a female (226 mm TL) whose ovaries were approximately 20% full of ova was collected. These ova were mushy in appearance rather than yellow and granular characteristic of ova found in ovaries of mature gravid females. This particular female had probably spawned only part of her ova and the rest were being re-absorbed. A few other females were examined and similar conditions observed. On July 24, and August 2, 1973, shoreline seining of Stagecoach reservoir at dusk yielded abundant young-of-the-year white perch.

During the spring of 1974 concentrations of white perch in Stagecoach reservoir, mostly males at first, were again observed in shallow water. On April 24, 1974 the reservoir was electrofished when the water temperature was 14.4°C. Hundreds of white perch of all sizes were shocked and 39 were netted for examination. Of these, 30 were male and 9 were female. Two of the males (216 mm and 224 mm TL) were spawning ripe. All other mature males and females were latent or gravid. Two weeks later (May 8, 1974) the reservoir temperature had increased to 18.3°C and hundreds of white perch were again electroshocked. Females were examined and although no female was spawning ripe, their ovaries contained translucent ova. Some males however, were spawning ripe.

In mid-afternoon May 22, 1974 white perch were observed spawning along the shore of Wagon Train reservoir where the water temperature was 22.5°C. Six schools, each with 25-50 individuals, were clearly observed in water .3 m or less in depth. Some schools milled about close to beds of *Polygonum* and *Phalaris arundinacea.* Each school would mill about then become quiescent after which one or two individuals would swim a short distance. Immediately there would be a milling of the whole school. Presumably the individuals that moved first were females spawning followed by males fertilizing the eggs. The slightly turbid conditions of Wagon Train's water prevented actual viewing of the spawned eggs. Bluegill, *Lepomis macrochirus,* and gizzard shad, *Dorosoma cepedianum*, were actively following one school and eating white perch eggs as they were desposited. White perch were observed the next day spawning around the entire perimeter of Wagon Train reservoir. There appeared to be no preference as to the type of habitat used for spawning and egg deposition other than that it occurred in shallow water. Foster (1919) also reported that landlocked white perch have no preference as to spawning site. In an effort to determine if white perch spawn at night observations after dark were made. The audible splashing of spawning carp was evident, but no schools of white perch were observed. If white perch spawn at night, they do so at a reduced level.

On June 12, 1974 Stagecoach reservoir was again sampled. All individuals examined had sunken abdomens and all gonads examined were spent. By the end of June and the first part of July white perch 40 mm-50 mm total length were abundant along the shores of the reservoir.

In Buckley 3F reservoir, field notes by Peters (1980) also indicated spawning activity (ripe females and males flowing milt) of white perch occurred in late May. Gonadal – Somatic Indexes for females peaked toward late May, 1979 when water temperatures ranged from 15 to 20°C.

In Nebraska, white perch reach a spawning condition during the month of May with most spawning occurring the last week of May and the first week in June. Water temperatures in Stagecoach and Wagon Train reservoirs during the spawning periods of 1973 and 1974 ranged from 14.4 to 23.3°C. Thorpe (1942) stated marine forms of white perch spawn during April and May while Stroud (1952) reported that white perch inhabiting fresh water of its native range spawn during May and June.

Ryder (1887), Titcomb (1908), and Foster (1919), cultured white perch eggs, and reported little development of the eggs at 7.2°C. At a temperature of 11.1 to 11.6°C white perch eggs hatched in six days. When the water temperature was increased to 14.4°C the eggs hatched in four to four and one-half days, and at 15.5°C they hatched in 24-30 hours. Mansueti (1964) cultured white perch eggs at 18.3°C and reported that most eggs hatched between 44 to 54 hours after fertilization. Prolarvae, postlarvae, and young white perch development were also thoroughly covered by this author.

Because of their fast growth, Nebraska white perch mature at age I or at 102 mm to 127 mm TL. Early maturity, the ability to spawn in a variety of habitats, and ideal water temperatures in Stagecoach and Wagon Train reservoirs during the peak spawning period are reasons why large year classes of white perch have been produced in the study reservoirs. Moreover, the success of white perch was aided by the availability of the right kind of food and the lack of suitable predators.

Fecundity

Ova from two mature females were used to estimate the mean diameter of the unfertilized egg. Two distinct size groups of ova were observed in all parts of the ovary and both sizes were measured in this determination. Conover (1958) made similar observations and proposed that the smaller ova were immature. A sample of 24 ova was measured from each of two white perch; a 167 mm TL, 65 gram, age group I, and a 256 mm TL, 234 gram, age III specimen. The age I fish had ova ranging from 0.4-0.7 mm with a mean diameter of 0.6 mm. Ova from the age III fish ranged from 0.3-0.7 mm with a mean diameter of 0.5 mm.

Fecundity, one of the best indicators of the reproductive potential of a species, is of special interest with regard to white perch in Nebraska. VanCamp (1949) reported that white perch, in parts of its native range, became sexually mature during the second year of life and spawn for the first time during the spring of the third year. In Nebraska, white perch reach sexual maturity at a length of about 127 millimeters or at an age of one year. In 1973, 34 white perch from Stagecoach reservoir were found to have a mean fecundity of 167,462 with a range of 16,374 to 463,720. All fish were age II and approximately the same length. Eighteen females of various sizes and ages collected from Wagon Train reservoir in 1973 had a mean fecundity of 34,746 with a range of 6,256-113,952 (Table 11). VanCamp (1949) and Carlander (1950) both state the average female white perch lays approximately 40,000 eggs. Taub (1966) found that in Quabbin Reservoir, Massachusetts, mature females in age groups III and IV had a mean fecundity of 271,000 ova with a range of 190,000 to 321,000.

Regressions were run on fecundity estimates (Figures 1, 2, and 3) versus weight in grams, length in millimeters, and age for white perch from Wagon Train reservoir. High correlation coefficients ($r = 0.9$) were found between fecundity and each of the three parameters. The coefficients of determination (R^2), derived by squaring the correlation coefficients, represent the amount of variability in fecundity which can be attributed to each variable. When analyzed separately, weight, length, and age accounted for 89%, 87%, and 88% of the variation in fecundity of Wagon Train white perch.

Multiple regressions with the variables of weight, length, and age were also run. Weight and age produced a highly significant R^2 value of 0.9 meaning that 90% of the variability in Wagon Train white perch fecundity could be attributed to weight and age combined. This R^2 value is not much higher than that found for any one individual variable due to the strong intercorrelation between the independent variables. The equation to calculate fecundity when weight and age are known is:

Fecundity = 1932.8 + 100.9 wt. + 9809.6 age

$R^2 = 0.90$

S.E. = 10,459

The high reproductive potential of Nebraska white perch, plus the ability to spawn successfully in a variety of habitats, may explain the unusually rapid expansion of white perch numbers after their introduction in Wagon Train and Stagecoach reservoirs, and may be the cause of their tendency to overpopulate most landlocked lakes.

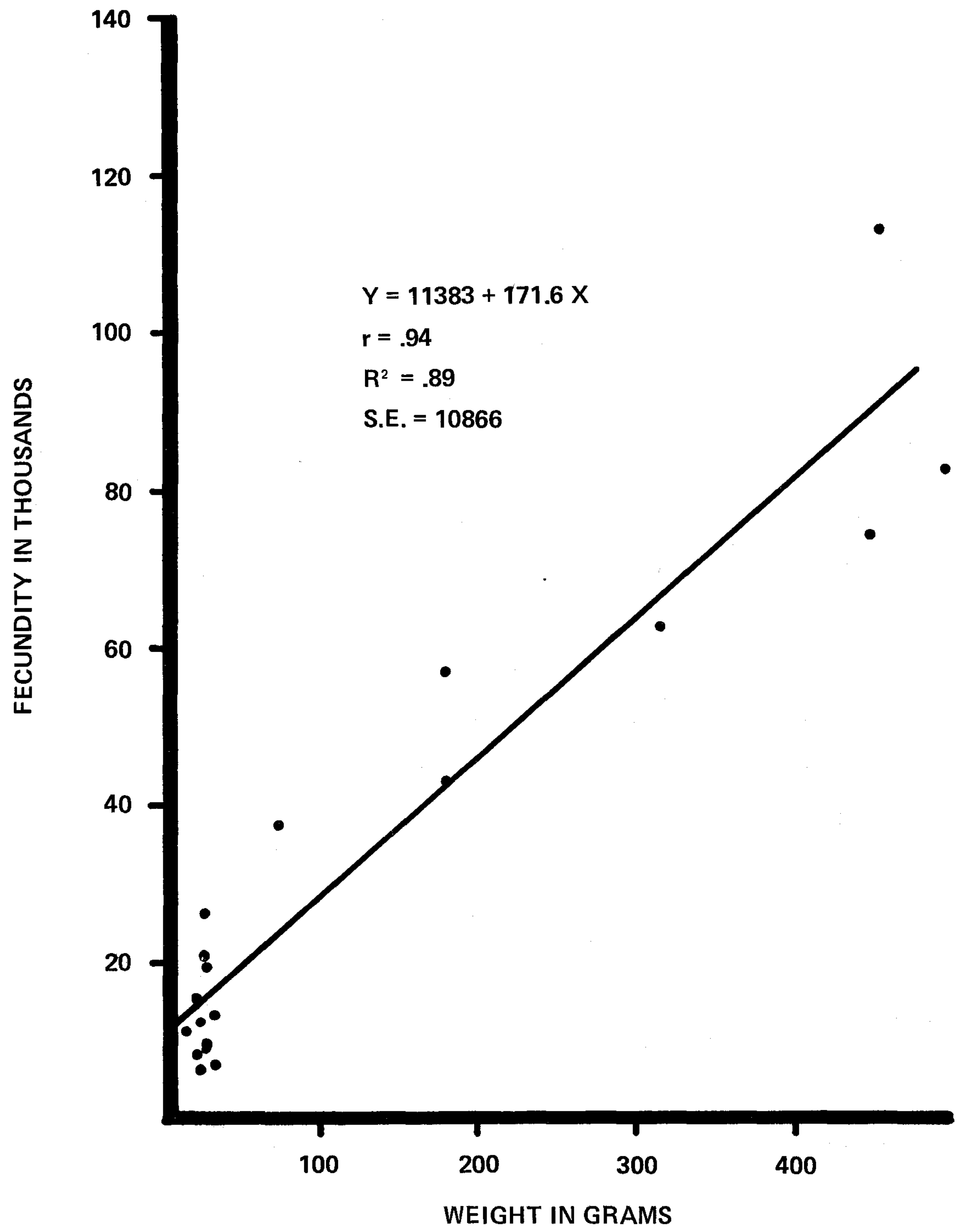

Figure 1. Relationship between fecundity and weight in 18 gravid female white perch captured in May and June, 1973 in Wagon Train Reservoir, Nebraska.

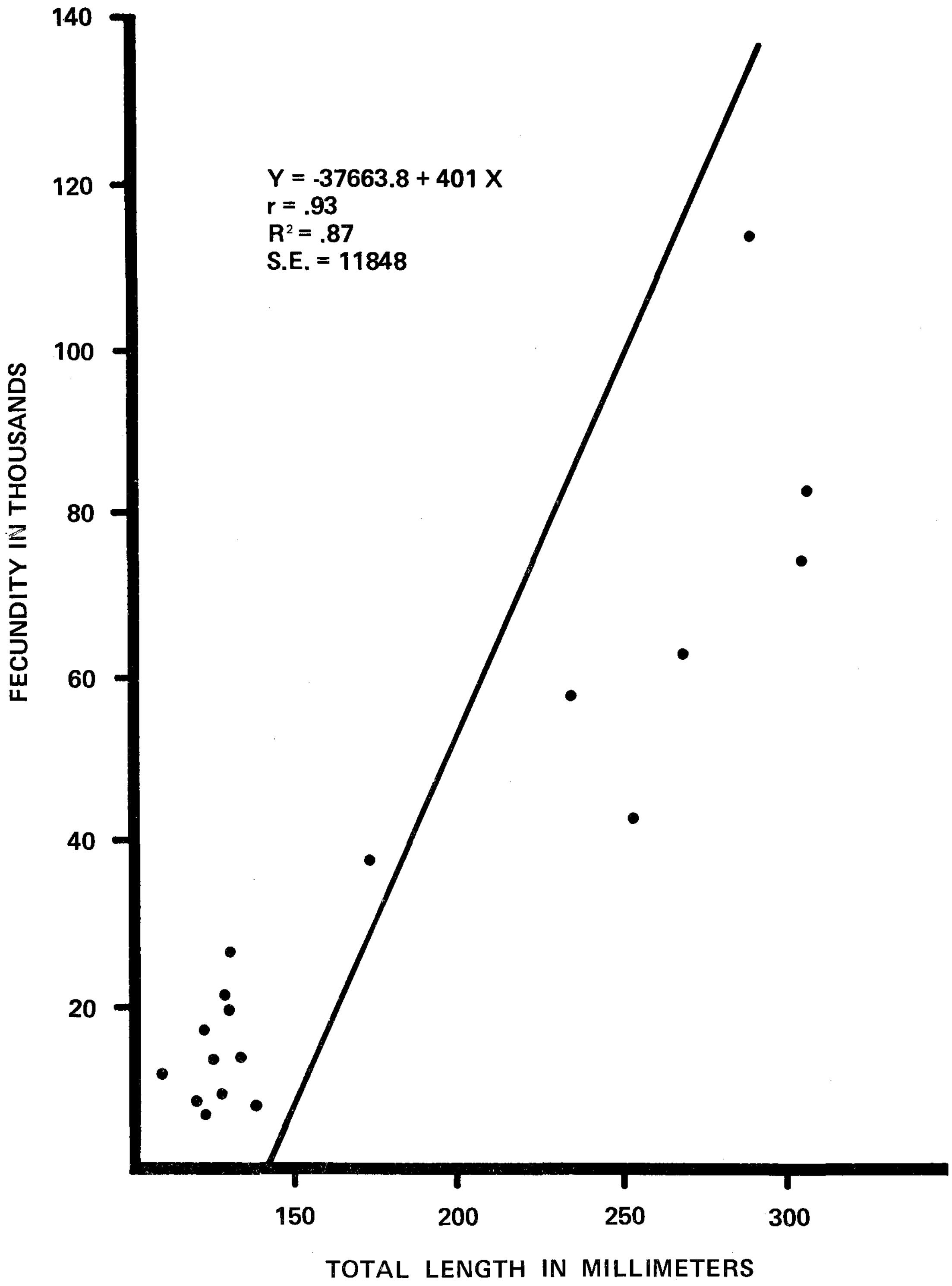

Figure 2. **Relationship between fecundity and total length in 18 gravid female white perch captured in May and June, 1973 in Wagon Train Reservoir, Nebraska.**

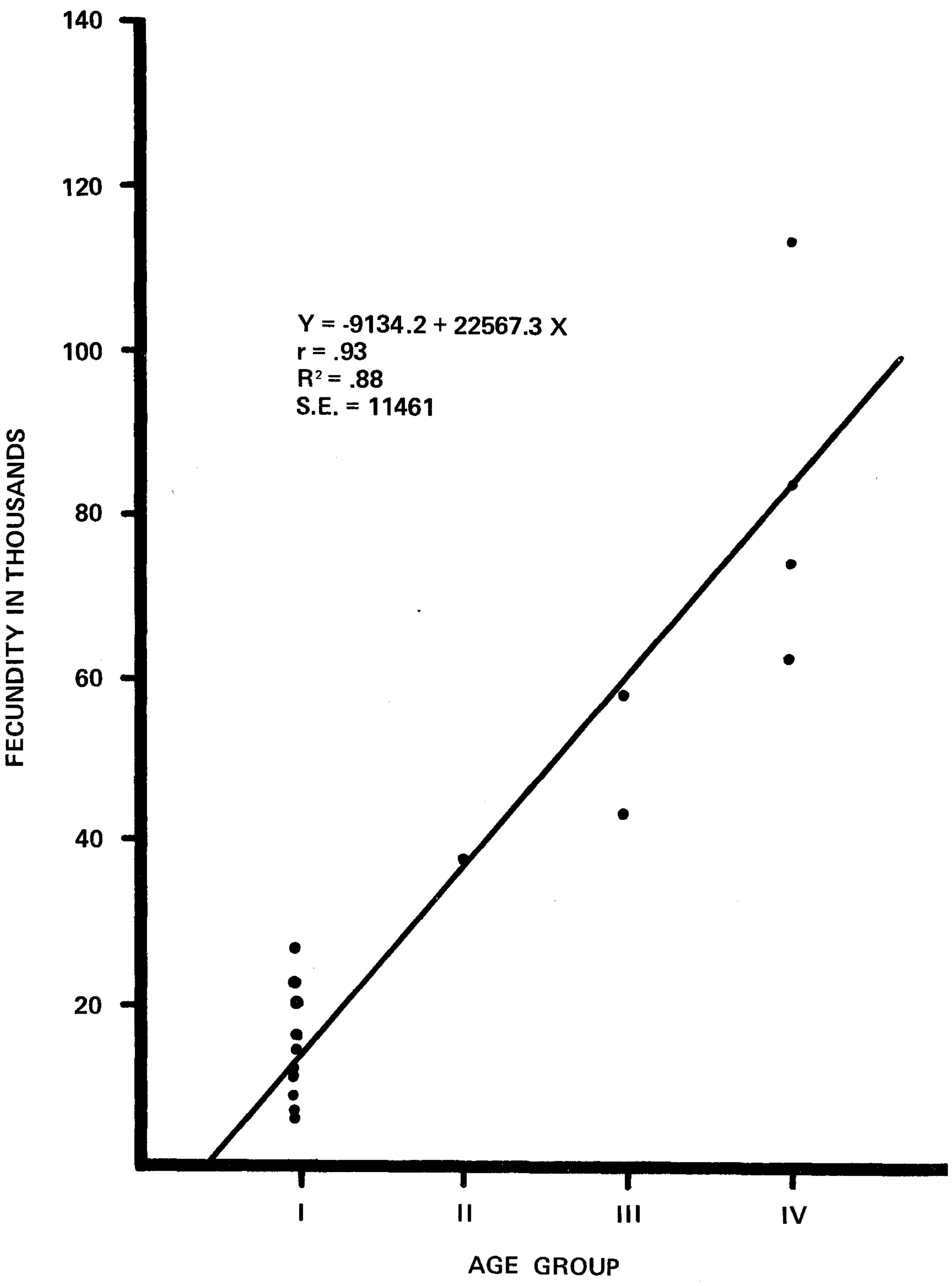

Figure 3. Relationship between fecundity and age in 18 gravid female white perch captured in May and June, 1973 in Wagon Train Reservoir, Nebraska.

Table 11. Estimated ova production of 18 white perch collected from Wagon Train reservoir in May and June, 1973.

Specimen	Total Length (mm)	Weight of fish (gms)	Age	Estimated ova
1	112	15	I	11,621
2	122	23	I	8,202
3	125	24	I	15,735
4	125	24	I	6,256
5	127	25	I	13,288
6	130	27	I	8,995
7	130	27	I	21,126
8	132	28	I	26,250
9	132	28	I	19,814
10	137	33	I	13,673
11	140	35	I	7,214
12	175	75	II	37,423
13	236	180	III	57,785
14	254	181	III	43,273
15	269	318	IV	62,973
16	292	454	IV	113,952
17	305	454	IV	74,536
18	307	499	IV	83,322
			Total	625,438

Mean fecundity = 34,746
Range = 6,256 – 113,952

Sex Ratio

A total of 976 white perch were sexed during standard 1973 and 1974 August surveys of Stagecoach reservoir. In 1973, out of 430 white perch examined, 237 were females and 193 were males (a sex ratio of 1.2:1.0). During the 1974 survey 546 white perch were examined of which 279 were females and 267 were males (a sex ratio of 1.1:1.0). The 1973 sex ratio was significantly different from 1:1 ($X^2 = 4.50$, $p < .05$) but the sex ratio in 1974 was not found to deviate from: 1:1 ($X^2 = 0.26$, $p < .50$).

Food Habits

During 1973 and 1974, 226 white perch stomachs were examined for food contents. Two-hundred and nine stomachs (92.5%) contained food items. Analyses consisted of determining frequency of occurrence, number, volume, and dry weight of the various prey items. Although there are advantages and disadvantages associated with each method of analysis, the importance of major food groups in the diet of white perch was readily ascertained by combining all four methods. Largemouth bass and black crappie stomachs were also analyzed and proved for the most part that white perch were seldom preyed upon by these species. For this reason the food habits of the bass and crappie will not be presented.

Frequency of occurrence demonstrates what organisms are being eaten, but it does not provide information on quantities or numbers, nor does it consider the accumulation of food organisms resistant to digestion. Consideration of only the numbers of food items found will often not give a true picture of the importance of different foods due to large differences in the size of individual items. Frequencies also are apt to be biased in favor of smaller items, though somewhat less so than numbers. Volumes on the other hand are biased in favor of large items because the latter are digested more slowly and thus are recognizable in the stomach for a longer period of time. Since the percentage of total volume of a food is not affected by frequency of occurrence, it does not reflect the food habits of individuals of a population but rather the foods consumed by the population as a whole (Ricker 1971).

Howmiller (1972) reported the effects preservatives have on the weight of common benthic macroinvertebrates. He found that commonly used preservatives, including 10% formalin, cause a great loss of wet and dry weight of worms and midge larvae. He also stated that since wet weights, and therefore presumably also dry weights, tend to reach a relatively constant value after about a month, it may be possible to obtain factors for back calculation to live weight or the dry weight. Although stomachs of fish in this study were preserved longer than 30 days before analysis, the poor condition of many food items examined prevented obtaining any factors for back calculating to true dry weight. For this reason the dry weight values arrived at in this study are probably somewhat lower than the true values.

During the 1973 Stagecoach investigation the stomach contents of 66 white perch, age 1 and 2 were analyzed. A total of 18 (100%) age 1 fish ranging in size from 127 - 191 mm contained food. Forty-three (89.6%) age 2 perch ranging from 191-272 mm also were found to contain food items. Data for these fish are presented in Tables 12 and 13. Based on frequency of occurrence age 1 fish in 1973 consumed primarily immature aquatic insects, fingernail clams, leeches, crustaceans, and fish. Immature aquatic insects, especially dipteran larvae (72.7%) occurred most frequently and were found in 77.8% of the stomachs. Fingernail clams were present in 22.2% of the stomachs, leeches in 16.7%, crustaceans in 16.7% and fish in 5.6%. Numerically, crustaceans made up 70.9% of the total number of food items, but on a volume and dry weight basis the importance of immature aquatic insects, especially dipteran larvae is clearly evident. Immature aquatic insects composed a major portion of the unidentifiable food category in all age groups throughout this study. Because of the degree of digestion their taxonomic classification could not be determined. If positive identification could have been established the importance of this food category would definitely have been reflected in values higher than those so reported.

Age II fish, based on frequency of occurrence in 1973, consumed organisms in the same sequence as age 1 fish, the only differnece being percentage values. Immature aquatic insects were present most frequently and were found in 93.0% of forty-three stomachs. Fingernail clams were present in 34.9% of the stomachs, leeches in 7.0%, crustaceans in 7.0% and fish in 2.3%. Note that the importance of zooplankton in the diet decreased from age 1 to age 2. Also, increased dependence on immature aquatic insects was evident, especially dipteran larvae, which were consumed by 93% of all fish. Values obtained from numerical (99.5%), volumetric (75.0%) and dry weight (65.6%) methods furthermore substantiate their importance. Because of their very small size fingernail clams are not believed to be as significant as their frequency of occurrence (34.9%) would indicate. Due to their burrowing habits (Pennak 1953, Gale 1971, Zumoff 1973), these pelecypods most likely were consumed incidently with the intake of other benthic organisms.

In 1974 the stomach contents of 160 white perch, ages 1, 2 and 3 were analyzed. A total of 9 (100%) age 1 perch ranging in size from 126-207 mm, 74 (96.1%) age 2 fish from 150-255 mm, and 65 (87.8%) age 3 fish from 196-264mm contained food items. These data are presented in Tables 14, 15 and 16, respectively. Based on frequency of occurrence age 1 fish consumed primarily immature aquatic insects, crustaceans, and leeches. Immature aquatic insects, especially dipteran larvae, again occurred most frequently and were found in 100% of the stomachs. Crustaceans were present in 33.3% of the stomachs and leeches in 11.1%. Based on the percentages of the three other methods, immature aquatic insects were still the most important constituent in the diet of age 1 fish.

Aquatic insect larvae, crustaceans, fingernail clams, fish, leeches, and aquatic vegetation were the major groups of food organisms consumed by age 2 white perch based on frequency of occurrence. Aquatic insect larvae were found in 90.5% of the stomachs. Crustaceans were found in 28.4% of the stomachs, fingernail clams in 18.9%, fish in 6.8%, leeches in 4.1%, and aquatic vegetation in 1.4%. Numerically aquatic insect larvae (54.8%) and crustaceans (44.7%) made up 99.5% of all items consumed. On a volume and dry weight basis also immature aquatic insects are clearly the most important. During 1974 two age 2 white perch were found to have eaten members of their own kind. Numerically fish made up an insignificant 0.1% of all items, but on a volume and dry weight basis they made up 11.4% and 51.4% respectively of the volume and dry weight totals. This ranks fish second only to aquatic insects for age 2 fish. However, fish were consumed only 6.8% of the time which indicates that they were not an important constituent in the diet of white perch.

Age 3 fish depended principally on insect larvae just as age classes 1 and 2 did. Based on frequency of occurrence age 3 fish consumed mostly aquatic insect larvae (86.2%) followed by crustaceans (20.0%), leeches (9.2%), fingernail clams (7.7%), fish (3.1%), and aquatic vegetation (1.5%). Even though few fish fry were consumed, their volume and weight made up 6.7% and 14.9% of these two categories. One white perch was identified from one age 3 perch stomach. That only 3.1% of these perch consumed fish is further evidence that they were not an essential constituent in the white perch diet. Fish eggs were found in five white perch stomachs, all of which were collected during the month of April when water temperatures were approximately 14.4°C. Based on the size of these eggs, the water temperature, and locality in which the fish collected had consumed the eggs (off of dam), it is believed they were walleye *Stizostedion vitreum* eggs.

Several points pertaining to the food habits of white perch in Stagecoach reservoir need to be emphasized. In 1973 zooplankton were found in two stomachs (11.1%) of age 1 fish but no age 2 fish contained them (Table 12, 13). In 1974 two age 1 (22.2%), twelve age 2 (16.2%), and three age 3 (4.6%) fish had consumed zooplankton (Tables 14, 15, 16). Evidently as the fish becomes older there is less reliance on zooplankton as a source of food.

The nutritional value of all pelecypods must certainly have been low due to their small size. Because of their burrowing habits (Pennak 1953; Gale 1971; Zumoff 1973) very likely they were consumed incidentally with the intake of other benthic macroinvertebrates. In 1973 only one age 1 fish out of 18 (5.6%) and one age 2 fish out of 43 (2.3%) examined had consumed any fish. In 1974 fish were found in 5 stomachs (6.8%) of age 2 and 2 stomachs (3.1%) of age 3 white perch of which two of the age 2 (2.7%) and one of the age 3 (1.5%) fish had consumed smaller white perch. Evidently this species will prey on its own kind, although fish fry did not play as important a role in the diet as other authors have found. This may be partly attributable to the short time span in which fry are vulnerable to predation. Insects, usually dipteran larvae, constituted the primary food of white perch ages 1 through 3. Lessig (1971), in his study of the macrobenthic fauna of Stagecoach reservoir found that immature Diptera composed 85.4% and 89.3% of the biomass per square meter in 1969 and 1970. The importance of Diptera in the diet of white perch has been reported by other investigators (Cooper 1941; Webster 1942; Smith 1947; Taub 1966). Goode (1903) reported that white perch will feed on the spawn of fishes, particularly shad, if the opportunity presents itself. Snow et al. (1970) stated white perch very likely prey upon the eggs and fry of yellow perch, pumpkinseed, black crappie, bluegill, largemouth and smallmouth bass.

The diets of many species of fish change with increasing size and age thereby making use of larger food items. That there appeared to be no clear diet transition in Nebraska white perch age 1 through 3 could explain the drastic decline in growth observed in Stagecoach white perch after age 2 (Table 3).

Thirty one age 0 white perch stomachs were examined from Buckley 3F reservoir in 1977 (Lund 1978a). Based on frequency of occurrence young of year perch fed predominately on crustaceans and aquatic insects. Copepods (80.6%) were most often utilized followed by seed shrimps (Ostracoda, 32.3%). The principal aquatic insects consumed were dipterans (Chironomidae, 32.3%) and trichopterans (Caenis, 16.1%). Understandably, high suspended solids and subsequent turbid conditions precluded high productivity in this reservoir. Total production of benthic insects averaged 688 larvae/m^2 and attest to the fact that harsh conditions existed. Nevertheless, white perch adapted to this environment and flourished.

Table 12. Stomach contents of white perch captured in Stagecoach Reservoir, Nebraska in 1973 (Age Class 1).

Item	% Frequency of Occurrence*	% Numerical Method	% Volumetric Method	% Dry Weight Method
Hirudinea	16.7	.1	3.4	3.1
Glossiphoniidae	16.7	.1	3.4	3.1
Crustacea	16.7	70.9	3.9	2.2
Zooplankton (Copepoda & Cladocera)	11.1	70.7	3.6	2.1
Amphipoda (scuds)	5.6	.2	.3	.1
Hydracarina	-	-	-	-
Pelecypoda	22.2	.2	.3	.2
Sphaeriidae (fing. clam)	22.2	.2	.3	.2
Insecta	77.8	28.8	23.2	20.8
Ephemeroptera	33.3	.8	3.6	6.6
Odonata	16.7	.1	1.3	.4
Hemiptera	-	-	-	-
Tricoptera	5.6	.1	.5	.1
Diptera	72.7	27.9	17.8	13.7
Culicidae	50.0	3.6	2.6	1.6
Chironomidae	72.7	21.3	12.8	9.8
Ceratopogonidae	50.0	3.0	1.9	1.3
Pisces	5.6	.1	5.4	4.4
Leopomis macrochirus	5.6	.1	5.4	4.4
Perca flavescens	-	-	-	-
Unidentifiable fry	-	-	-	-
Unidentifiable matter (all types)	61.1	-	63.9	69.4

Sampling time period June - October, 1973

Total number of stomachs examined 18
Total number of stomachs containing food 18 (100%)
Size range of fish examined 127-191 mm

*Percent frequency of occurrence based on number of stomachs containing food items.

Table 13. Stomach contents of white perch captured in Stagecoach Reservoir, Nebraska in 1973 (Age Class 2).

Item	% Frequency of Occurrence*	% Numerical Method	% Volumetric Method	% Dry Weight Method
Hirudinea	7.0	.1	1.2	1.2
Glossiphoniidae	7.0	.1	1.2	1.2
Crustacea	7.0	.1	.2	.1
Zooplankton (Copepoda & Cladocera)	-	-	-	-
Amphipoda (scuds)	7.0	.1	.1	.1
Hydracarina	2.3	.1	.1	.1
Pelecypoda	34.9	.4	.4	.3
Sphaeriidae (fing. clam)	34.9			
Insecta	93.0	99.5	75.0	65.6
Ephemeroptera	37.2	.8	2.5	3.0
Odonata	4.7	.1	.1	.1
Hemiptera	9.3	.1	.2	.1
Tricoptera	-	-	-	-
Diptera	93.0	98.6	72.3	62.5
Culicidae	86.1	82.9	66.4	56.9
Chironomidae	69.8	12.9	4.9	4.8
Ceratopogonidae	81.4	2.8	1.0	.8
Pisces	2.3	.1	6.7	12.4
Lepomis macrochirus	2.3	.1	2.1	1.6
Perca flavescens	2.3	.1	3.0	9.5
Unidentifiable fry	2.3	.1	1.6	1.3
Unidentifiable matter (all types)	46.5	-	16.6	20.5

Sampling time period June-October, 1973

Total number of stomachs examined 48
Total number of stomachs containing food 43 (89.6%)
Size range of fish examined 191-272 mm

*Percent frequency of occurrence based on number of stomachs containing food items.

Table 14. Stomach contents of white perch captured in Stagecoach Reservoir, Nebraska in 1974 (Age Class 1).

Item	% Frequency of Occurrence*	% Numerical Method	% Volumetric Method	% Dry Weight Method
Hirudinea (leeches)	11.1	.2	3.7	4.4
Glossiphoniidae	11.1	.2	3.7	4.4
Crustacea	33.3	11.3	5.1	4.3
Zooplankton (Copepoda & Cladocera)	22.2	11.2	4.8	4.3
Amphipods (scuds)	11.1	.1	.3	.1
Insecta (immature)	100.0	88.5	55.0	65.6
Ephemeroptera	55.6	2.4	22.4	37.4
Hemiptera	22.2	1.1	1.9	1.3
Diptera	77.8	85.0	30.7	26.9
Culicidae	22.2	.5	.3	.1
Chironomidae	77.8	79.1	27.3	25.8
Ceratopogonidae	66.7	5.4	3.1	1.0
Aquatic vegetation	-	-	-	-
Unidentifiable matter (all types)	-	-	36.2	25.6

Sampling time period March - November, 1974
Total number of stomachs examined 9
Total number of stomachs containing food 9 (100%)
Size range of fish examined 126-207 mm

*Percent frequency of occurrence based on number of stomachs containing food.

Table 15. Stomach contents of white perch captured in Stagecoach Reservoir, Nebraska in 1974 (Age Class 2).

Item	% Frequency of Occurrence*	% Numerical Method	% Volumetric Method	% Dry Weight
Hirudinea (leeches)	4.1	.1	1.0	1.0
Glossiphoniidae	4.1	.1	1.0	1.0
Crustacea	28.4	44.7	8.9	9.2
Zooplankton (Copepoda & Cladocera)	16.2	44.5	8.3	9.1
Amphipods (scuds)	13.5	.2	.6	.1
Pelecypoda	18.9	.4	.7	.1
Sphaeriidae (fing. clams)	18.9	.4	.7	.1
Insecta (immature)	90.5	54.8	43.6	36.4
Ephemeroptera	27.0	2.0	3.9	6.9
Odonata	2.7	.1	.4	.1
Homoptera	1.4	.1	.1	.1
Tricoptera	4.1	.1	.2	.1
Diptera	82.4	52.6	38.9	29.3
Culicidae	31.1	1.5	1.0	.6
Chironomidae	81.1	43.5	35.8	27.2
Ceratopogonidae	70.3	7.6	2.1	1.5
Coleoptera	1.4	.1	.1	.1
Pisces	6.8	.1	11.4	21.4
Leopmis macrochirus	2.7	.1	3.0	5.4
Morone americana	2.7	.1	3.9	8.7
Unidentifiable young of year	1.4	.1	4.6	7.4
Pisces Eggs	1.4	-	.1	.1
Aquatic vegetation	1.4	-	.1	.1
Unidentifiable matter (all types)	33.8	-	34.1	31.7

Sampling time period March - November 1974

Total number of stomachs examined 77
Total number of stomachs containing food 74 (96.1%)
Size range of fish examined 150-255 mm

*Percent frequency of occurrence based on number of stomachs containing food items.

Table 16. Stomach contents of white perch captured in Stagecoach Reservoir, Nebraska in 1974 (Age Class 3).

Item	% Frequency of Occurrence*	% Numerical Method	% Volumetric Method	% Dry Weight Method
Hirudinea	9.2	.3	3.7	3.5
Glossiphoniidae	9.2	.3	3.7	3.5
Crustacea	20.0	9.0	1.5	1.6
Zooplankton (Copepoda & Cladocera)	4.6	7.6	0.9	1.4
Amphipoda (scuds)	15.4	1.4	0.6	.2
Pelecypoda	7.7	.3	.2	.1
Spaeriidae (fing. clam)	7.7	.3	.2	.1
Insecta (immature)	86.2	90.3	46.4	43.8
Ephemeroptera	35.4	6.4	17.3	12.0
Odonata	7.7	.3	2.6	2.9
Tricoptera	3.1	.1	.1	.1
Diptera	81.5	82.9	26.0	28.4
Culicidae	33.8	1.6	.5	.1
Chironomidae	73.8	65.6	23.2	25.9
Ceratopogonidae	66.2	15.3	1.9	1.8
Tabanidae	9.2	.4	.5	.6
Coleoptera	9.2	.5	.4	.4
Pisces	3.1	.1	6.7	14.9
Lepomis macrochirus	1.5	.1	1.3	3.2
Morone americana	1.5	.1	3.5	7.6
Unidentifiable young of year	1.5	.1	1.9	
Pisces Eggs	7.7	-	8.2	8.2
Aquatic vegetation	1.5	-	3.8	1.8
Unidentifiable matter (all types)	50.8	-	29.6	26.3

Sampling time period March-November, 1974

Total number of stomachs examined 74
Total number of stomachs containing food 65 (87.8%)
Size range of fish examined 196-264 mm

*Percent frequency of occurrence based on number of stomachs containing food items

Population Inventories

Wagon Train Reservoir: Black bullhead and bluegill were the two most abundant species comprising the sport fishery of Wagon Train reservoir in 1965 and 1966 (Tables 17 and 18). Although the white perch constituted less than 1.0% of the total fish captured in a 1965 fishery survey, this species had completely displaced the black bullhead as the dominant species by 1967. This dominance continued through 1974. An occurrence of this sort by an exotic species in a new environment is not surprising in view of the fact that at the time of their introduction a "balanced" fish population was not present in Wagon Train reservoir. Figures 4 and 6 depict the percent composition of white perch, bluegill, and black bullhead captured in gill nets (GN) and trap nets (TN) from 1965 through 1974. Figures 5 and 7 illustrate the catch per unit effort of these species in gill nets and trap nets during the same period. These figures suggest that the large numbers of white perch and the decline of the black bullhead population were interrelated. Exactly how is not known but the black bullhead is an omnivore (Cross 1967) that relies extensively on aquatic insects as food. Since white perch also depend heavily on immature aquatic insects, interspecific and intraspecific competition for food very likely was present. By examining population trends as exemplified by the percent composition of gill nets and trap nets combined since 1965 (Figure 13) the presumed detrimental influence of white perch on the black bullhead is even more apparent.

In 1968 bluegill numbers reached their highest level (Table 18 and Figure 6) since their introduction into Wagon Train reservoir followed by a decline in 1969 to below pre-1968 levels. Examination of the percent composition and catch per unit effort after 1968 reveals that although the bluegill population fluctuated somewhat it remained at a low level. This is also apparent in Figure 8. Normally, bluegill provide a good forage species in eastern Nebraska waters and often overpopulate and stunt when an imbalance between predator and prey develops. Attempts to maintain predator populations in Wagon Train reservoir met with little success and therefore one would expect large numbers of bluegill to occur. Instead, periodic maintenance stockings of predators and the bluegill, were necessary. Wagon Train is a turbid reservoir, consequently suitable aquatic vegetation for bluegill (especially the young-of-year) cover is non-existent. The invertebrate diet of this species (especially aquatic dipteran larvae, Morris 1964; Seaburg and Moyle 1964; Gengerke 1972) and the results obtained in the food habits study of white perch in Stagecoach reservoir, indicates that there was competition between these two species for the same food supply. Snow et al. (1970) believe that white perch prey upon the eggs of bluegill. It is apparent that white perch, at least in part, were responsible for the suppression of bluegill in Wagon Train reservoir.

Black crappie were able to increase in Wagon Train reservoir in spite of the white perch presence. This was attributed to the lack of competition for food between the species, the black crappie being primarily a planktivore.

Stagecoach Reservoir: Originating from a single 1963 stocking, bluegill until recent years made up a substantial part of the fishery in Stagecoach reservoir (Tables 19 and 20). Largemouth bass and bluegill provided most of the sport fishery in 1970 (Messman 1971) while no white perch were sampled in a population survey of that year. A single white perch was sampled with an otter trawl in the fall of 1971. The establishment of white perch in Stagecoach reservoir was verified in a 1972 fish population survey where this species made up 27.5% of the gill net catch (Table 19). During the next two years, white perch numbers expanded tremendously, increasing 100% or more in the gillnet catch with each succeeding year. White perch completely dominated the gill net catch in 1972, 1973, 1974, and 1975. This rapid expansion and ultimate predominance of white perch was somewhat surprising in view of the fact that an established fishery with several piscivorous species existed in Stagecoach reservoir at the time.

Exactly how white perch gained entry into Stagecoach reservoir cannot be positively ascertained but an "unofficial" stocking by a well intentioned fisherman was probably responsible. The presence of white perch with three annuli in 1972 suggest that entry was made into Stagecoach reservoir in the spring of 1970. No white perch had been sampled in 1970 but the presence of a 1970 year-class indicates that the introduced fish also spawned in 1970. Young-of-the-year would not have been sampled in this year because they are too small to be collected with the gear used in surveying. The trawl sample of a single white perch in the fall of 1971 led to the suspicion that the species was much more prevalent in the reservoir and the 1972 survey confirmed their establishment (Table 19).

Although white perch resided in Wagon Train reservoir much longer than in Stagecoach reservoir, their densities in both reservoirs appeared to be similar in 1974. In that year the average catch of white perch per gill net was 95 in Stagecoach and 83 in Wagon Train. Comparison of the 1974 gill net data (Table 21) from both reservoirs, using the method presented by Moyle and Lound (1960), indicates that the high catch of white perch in Stagecoach was not significantly ($p \leq .07$) different from the catch in Wagon Train.

Table 17. Percent compositions of catch of different species caught in gill nets in various years, Wagon Train reservoir.

Species	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
White Perch	0.6	4.5	6.58	57.1	36.8	35.2	53.6	52.0		65.3
Black Bullhead	94.4	82.0	18.6	22.8	29.4	41.2	6.0	6.1		0.7
Carp	--	1.0	10.5	7.8	10.3	4.4	3.5	3.6	no	2.0
Gizzard Shad	--	--	0.3	7.6	10.3	7.7	22.0	23.0	survey	18.7
Channel Catfish	3.5	8.8	2.7	2.4	11.8	10.4	13.1	13.5		10.0
Bluegill	1.0	2.2	0.5	0.5	--	--	0.2	0.1		--
Black Crappie	--	--	0.3	0.6	1.5	1.1	0.5	0.5		2.9
Other Species	0.5	1.5	1.3	1.0	--	0.1	1.1	1.2		0.4
N =	887	1051	372	1870	68	937	1439	1378		1017

Table 18. Percent compositions of catch of different species caught in trap nets in various years, Wagon Train reservoir.

Species	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
White Perch	--	8.9	27.5	35.1	70.1	89.4	38.3	39.0		22.8
Black Bullhead	73.9	53.2	13.0	--	1.3	2.2	1.3	1.3		0.5
Carp	--	--	4.3	--	--	0.6	3.3	3.1	no	0.5
Gizzard Shad	--	--	18.8	--	6.5	4.3	3.1	3.1	survey	4.8
Channel Catfish	0.6	0.8	--	--	--	0.5	--	0.4		2.7
Bluegill	24.4	21.8	29.0	55.7	10.0	2.5	21.5	20.8		15.3
Black Crappie	--	--	5.8	8.5	10.4	0.2	30.5	30.3		50.3
Other Species	1.2	15.3	1.4	0.7	1.7	0.3	2.2	2.2		3.1
N =	180	124	69	697	231	3228	522	519		189

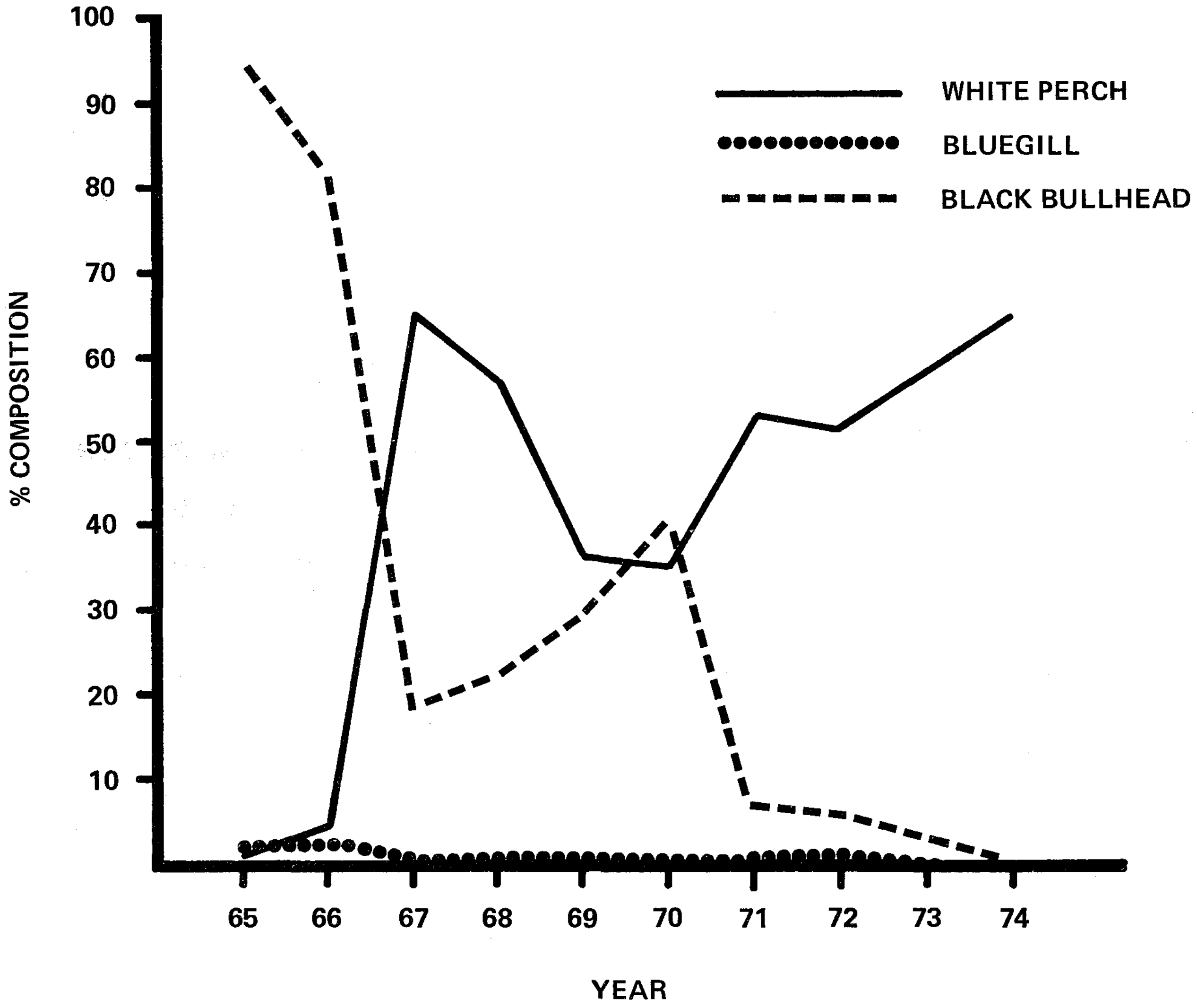

Figure 4. Percent composition of catch from gill nets in Wagon Train Reservoir.

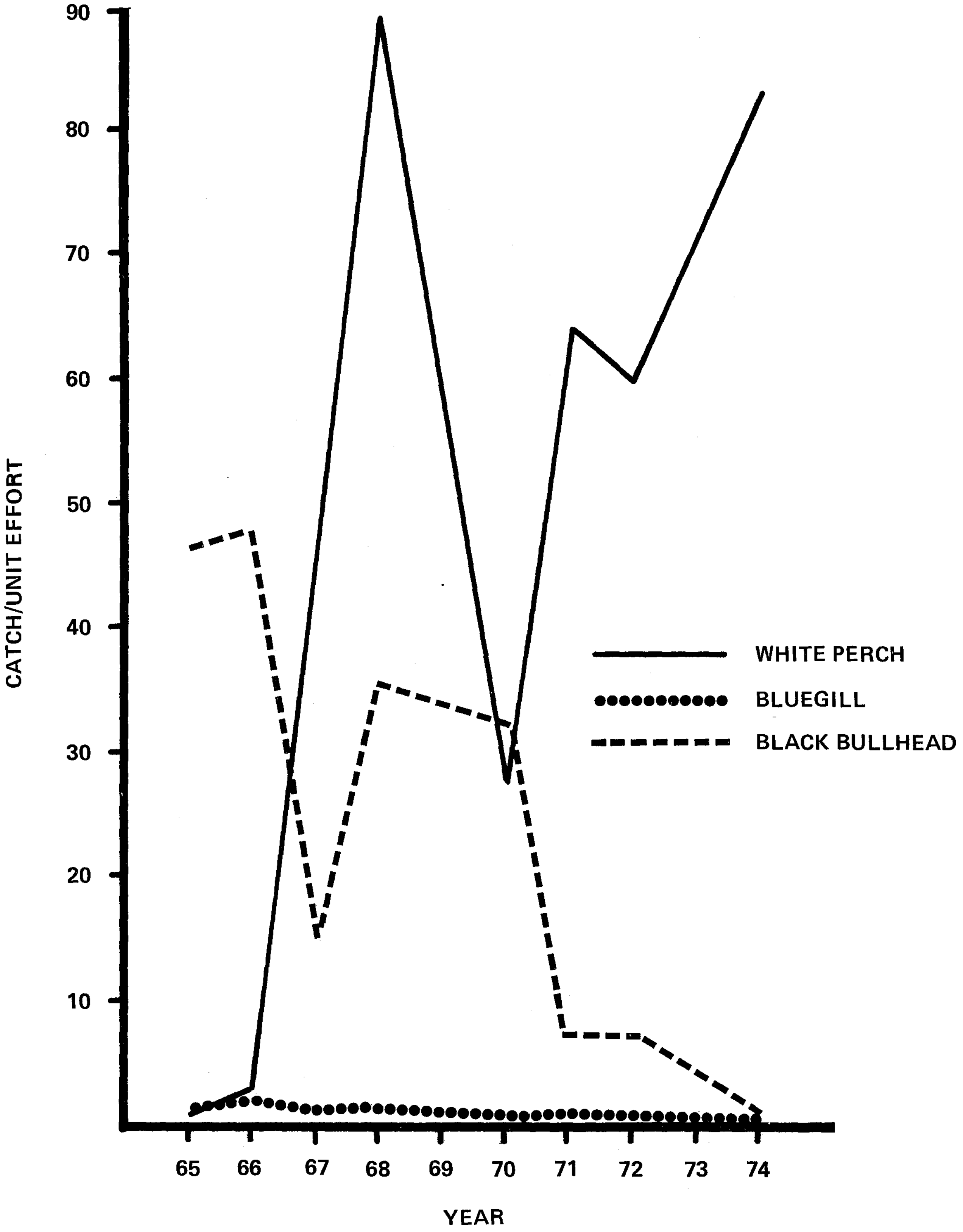

Figure 5. Catch per unit effort of gill nets in Wagon Train Reservoir.

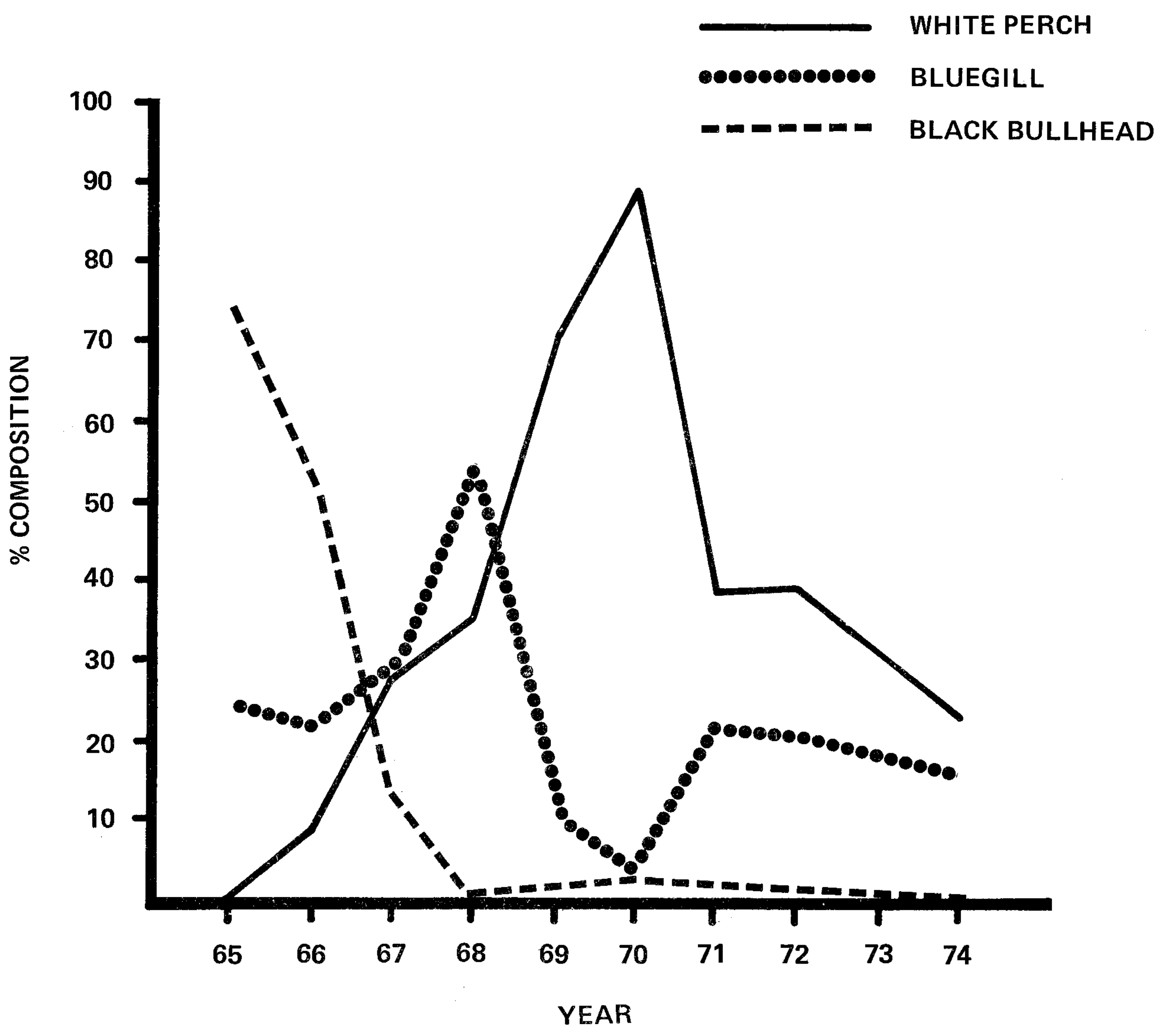

Figure 6. Percent composition of catch from trap nets in Wagon Train Reservoir.

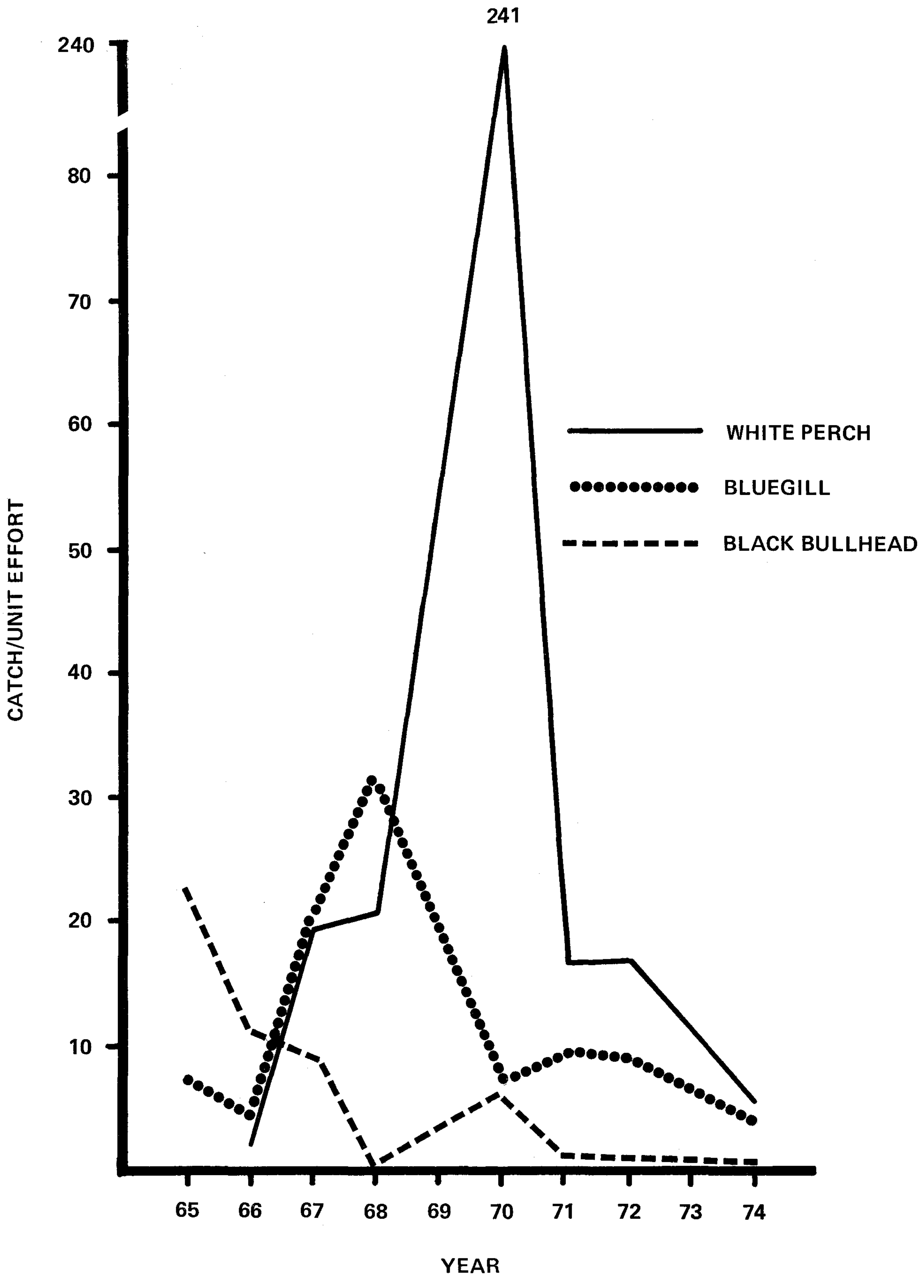

Figure 7. Catch per unit effort of trap nets in Wagon Train Reservoir.

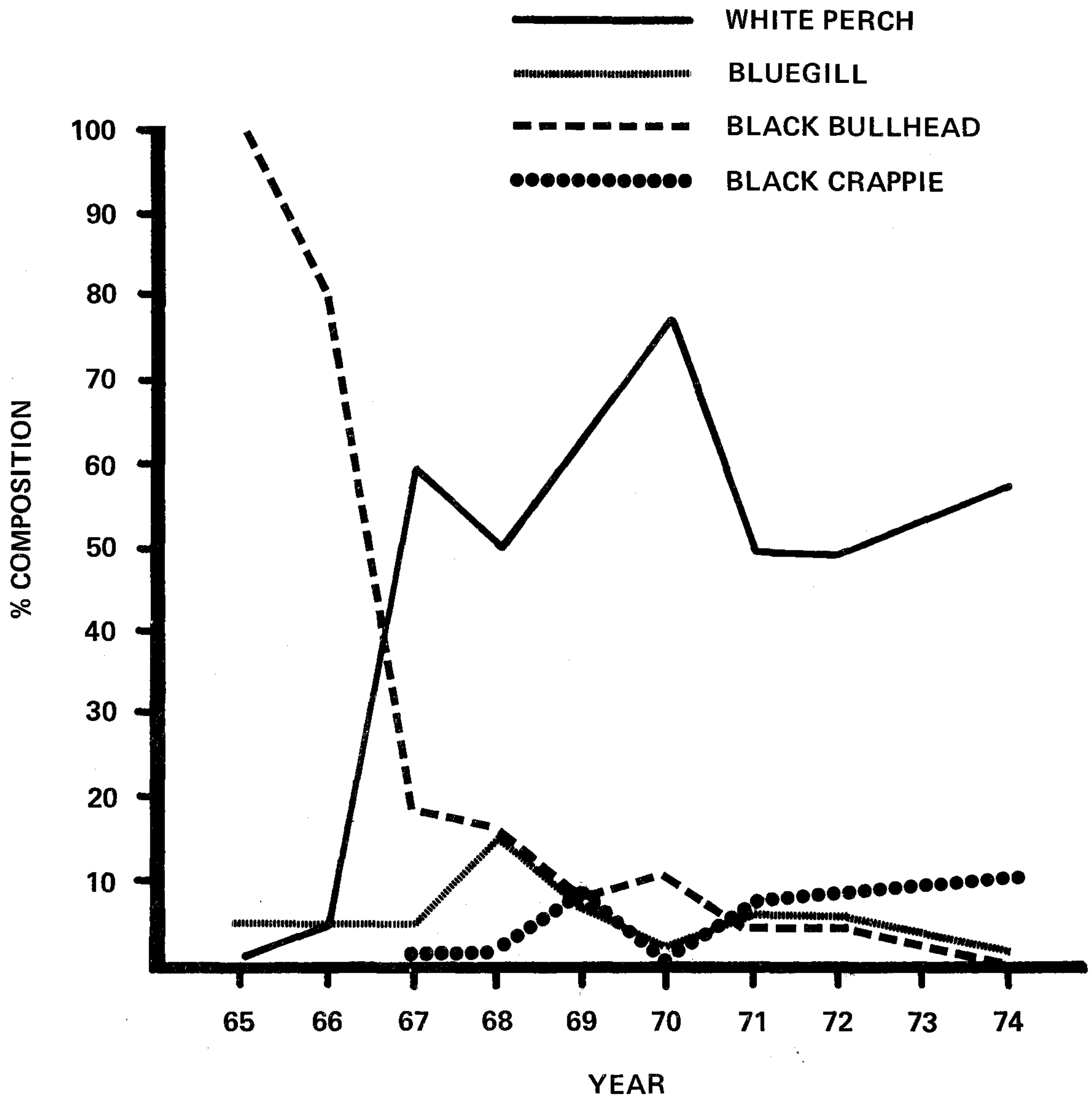

Figure 8. Percent composition of catch from gill and trap nets combined in Wagon Train Reservoir.

Table 19. Percent compositions of catch of different species caught in gill nets in various years, Stagecoach reservoir.

Species	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975
White Perch							*	27.5	38.3	60.5	50.6
Northern Pike	23.5	19.0	5.8	1.7		0.5		3.5	0.9	0.3	0.4
Walleye	10.4	29.7	18.5	13.6		21.1		3.2	1.8	0.6	1.0
Yellow Perch	--	--	--	0.3	no survey	8.9	no survey	17.4	15.2	15.6	13.0
Largemouth Bass	--	0.8	2.4	6.5		2.6		0.3	0.4	--	--
Bluegill	9.6	22.1	21.5	52.7		40.0		17.9	14.2	2.0	1.9
Channel Catfish	54.8	23.6	22.4	12.0		12.2		0.7	7.3	4.0	2.6
Black Bullhead	1.7	0.4	21.2	6.1		5.9		--	--	--	0.1
Black Crappie	--	--	--	--		3.0		11.2	10.0	5.4	5.2
Other Species	--	4.6	8.2	6.0		5.7		18.2	11.9	11.6	25.2
N =	115	263	330	294		271		724	1134	1884	1557

*A single white perch was taken in fall, 1971 by trawling.

Table 20. Percent compositions of catch of different species caught in trap nets in various years, Stagecoach reservoir.

Species	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975
White Perch							*	0.6	4.2	17.2	7.4
Northern Pike	4.8	14.5	1.3	1.3		0.3		0.6	2.1	0.7	0.4
Walleye	--	--	--	0.2		0.3		0.4	0.8	0.2	0.1
Yellow Perch	--	--	--	--	no survey	3.7	no survey	17.5	24.1	17.6	5.8
Largemouth Bass	19.4	58.2	7.7	0.9		1.5		0.4	0.8	--	0.4
Bluegill	48.9	23.6	66.7	69.5		85.7		54.5	46.5	16.3	27.9
Channel Catfish	--	--	--	0.2		--		--	0.4	--	--
Black Bullhead	8.1	--	--	6.0		0.9		--	--	--	0.8
Black Crappie	--	--	--	--		2.7		21.9	19.5	47.8	56.5
Other Species	18.7	3.6	24.4	25.4		4.8		4.1	1.6	0.2	0.7
N =	186	55	78	464		328		773	241	460	758

*A single white perch was taken in fall, 1971 by trawling.

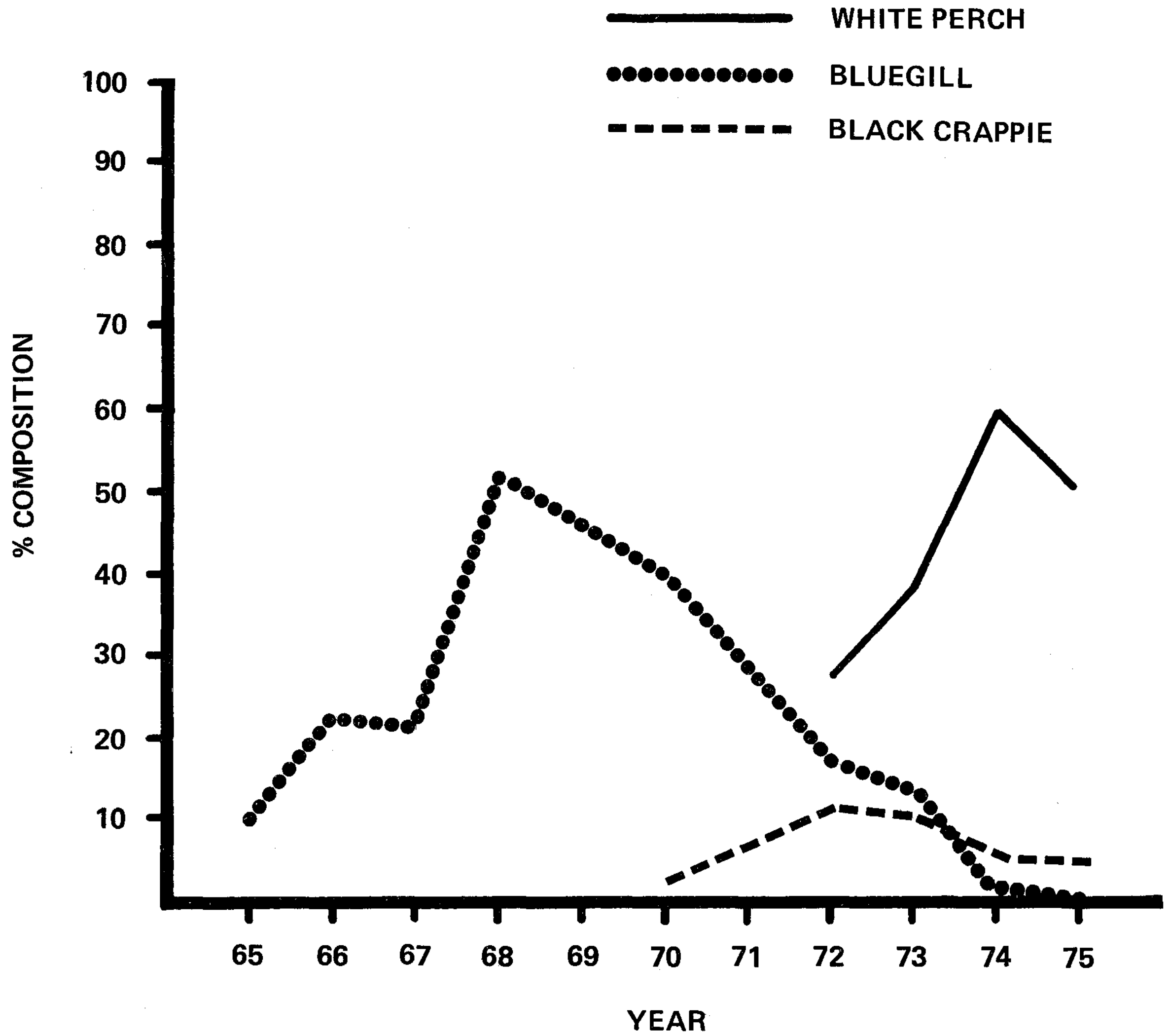

Figure 9. Percent composition of catch from gill nets in Stagecoach Reservoir.

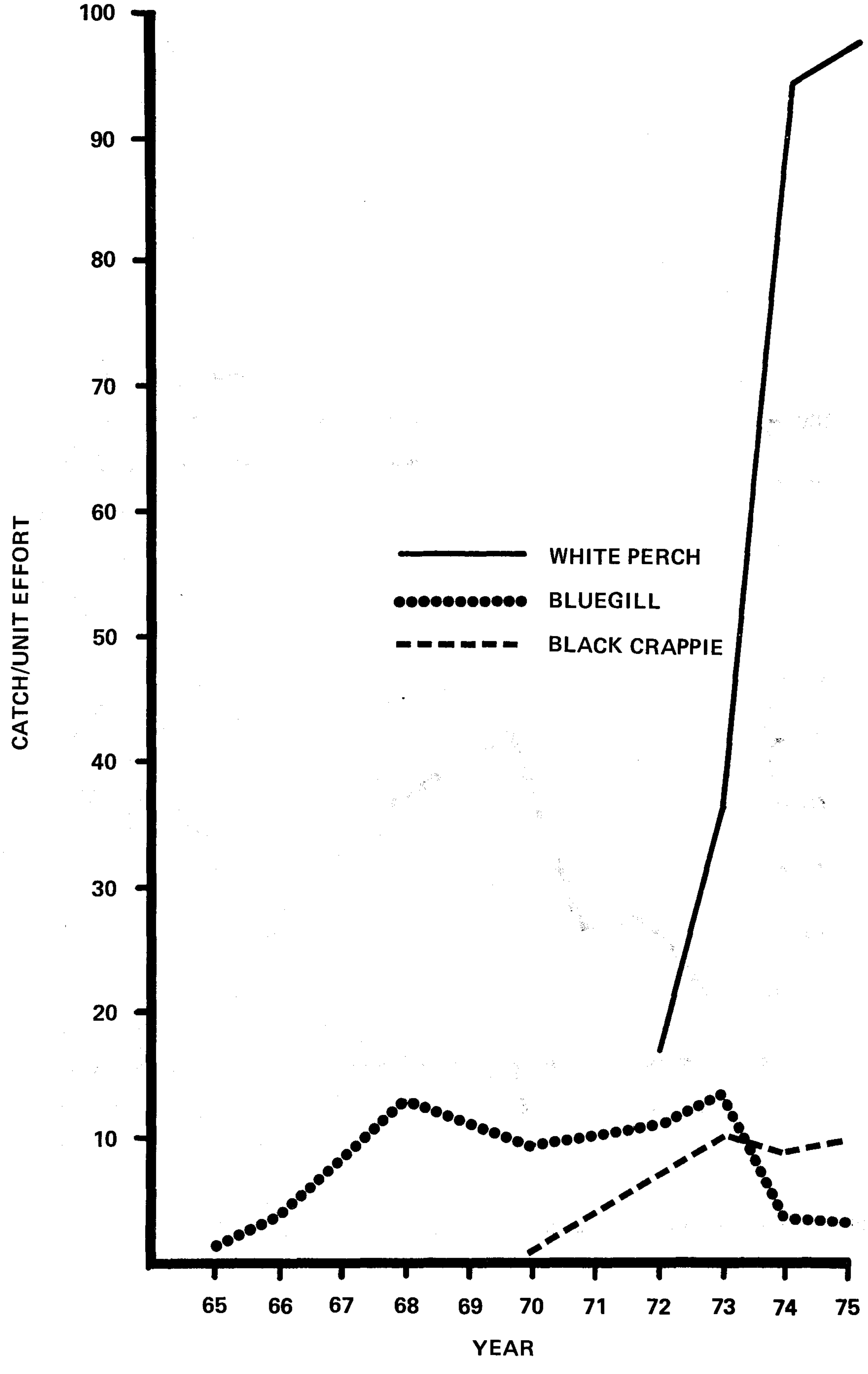

Figure 10. Catch per unit effort of gill nets in Stagecoach Reservoir.

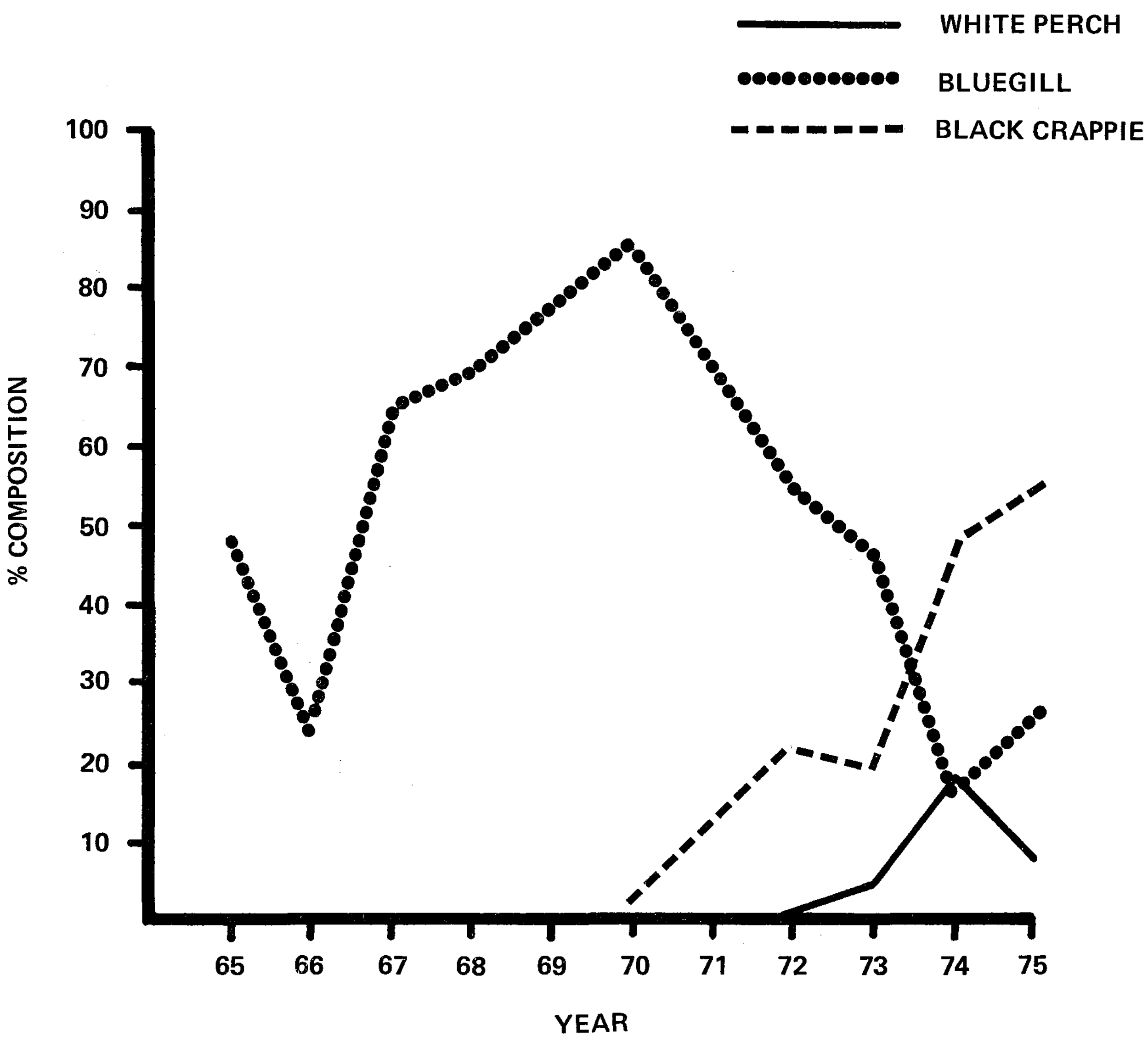

Figure 11. Percent composition of catch from trap nets in Stagecoach Reservoir.

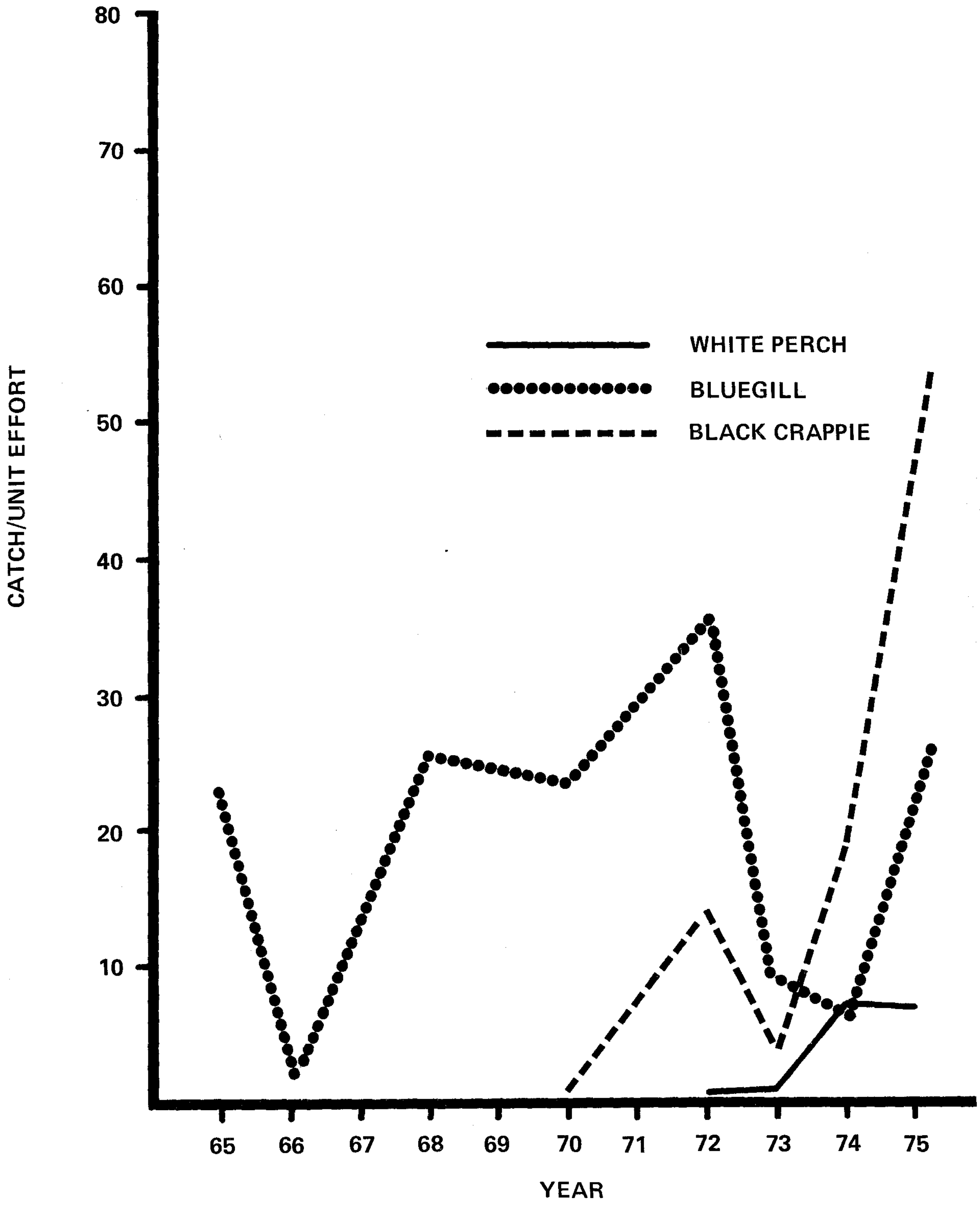

Figure 12. Catch per unit effort of trap nets in Stagecoach Reservoir.

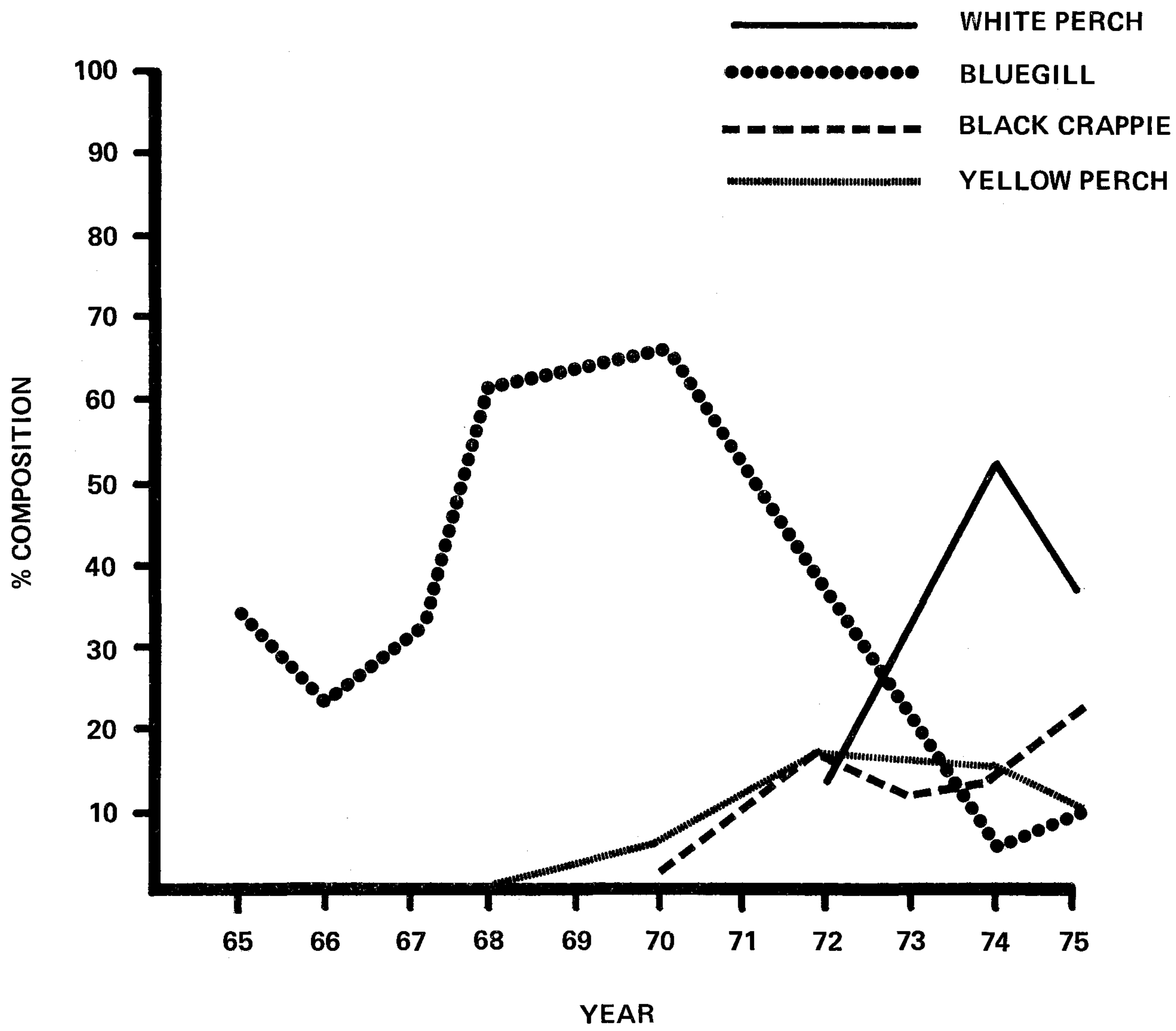

Figure 13. Percent composition of catch from gill and trap nets combined in Stagecoach Reservoir.

Table 21. **Catch of white perch in 12 gill nets in Stagecoach, 1974 and 8 gill nets in Wagon Train, 1974 with confidence limits of median catch (V).**

Reservoir	**Gill net arranged in ascending order**											**Confidence limits (p < .07)**
Stagecoach	52	70	(76)	77	80	85	89	103	(112)	131	188	76<V<112
Wagon Train	24	(54)	66	86	88	107	(119)	120				54<V<119

Note: ( ) = confidence intervals

p(76<V<112) = .96 for catch of 12 gill nets in Stagecoach.
p(54<V<119) = .93 for catch of 8 gill nets in Wagon Train.

As was the case in Wagon Train, the dominance of white perch in Stagecoach was quickly followed by a decline in the overall fishery. Figures 9 and 11 depict the percent composition of white perch, bluegill, and black crappie captured in gill nets (GN) and trap nets (TN) from 1965 through 1975. Figures 10 and 12 show the catch per unit of effort in gill nets and trap nets. The percent composition of white perch in both types of nets (combined) is given in Figure 13. From Figures 9, 11 and 13 it appears that the bluegill population greatly decreased after 1970. This is deceiving though because the absolute abundance of bluegill remained fairly constant as can be seen in the catch per effort trends shown in Figures 10 and 12. Increases in the populations of white perch, yellow perch, and black crappie are clearly responsible for the decrease in relative abundance of the bluegill. The absolute numbers of bluegill (Figure 12) decreased from 1972 to 1974 but increased in 1975. A plausible explanation for the decrease in 1973 and 1974 is intraspecific competition for food. Prior to and during 1968 bluegill were attaining 178-203 mm total length by age III with some individuals living to be four and five years old (Hutchinson 1967, 1968). From 1970 on, growth declined to 152 - 178 mm total length by age III with no individuals living to be older than age III (Zuerlein 1973, 1974, 1975). Although there was an observed decline in the growth rate, growth of bluegill was excellent compared to the growth of this species in other states (Calhoun 1966). Due to the rapid expansion of white perch numbers from 1972 through 1974, and to the similar food habits of both species, interspecific competition for food was one of the factors responsible for the decline of bluegill numbers after 1972.

Black crappie were able to increase their numbers in Stagecoach reservoir (Table 20) just as they had in Wagon Train reservoir (Table 18) in spite of the abundant white perch. This can be attributed to the food habits of black crappie. Based on the results of the Stagecoach food study, black crappie were predominantly plankton feeders through age III as Keast (1968) found to be true in Lake Opinicon, Ontario. Since white perch were, for the most part, benthic feeders, their food habits did not overlap with the plankton feeding habits of black crappie.

Management Approaches

From the results obtained in the 1973 and 1974 study of food habits of white perch, largemouth bass, and black crappie it appears that white perch are seldom eaten by these species. Perhaps due in part to an abundance of other food organisms during the growing season. Stagecoach reservoir was stocked with 94,093 northern pike fingerlings and 10,086 advanced fingerling walleye between 1971 and 1974 but survey results suggest limited survival. Observing the continued rapid increase in white perch numbers from 1972 to 1974 with no decline in growth and because of Thoits' (1958) documentation of the poor utilization of white perch by predators (largemouth bass, smallmouth bass, chain pickerel) in Massachusetts, it appears that stocking predators to control white perch is not a justifiable management approach in Nebraska.

In an effort to improve the poor quality sport fishery existing in Wagon Train reservoir a partial renovation, using antimycin, was conducted on June 3, 1974. The objectives of this partial renovation were: to improve largemouth bass recruitment, to improve conditions for survival of supplemental stockings of walleye, striped bass, and largemouth bass, and improve growth of game species by eliminating a sizable proportion of gizzard shad and white perch populations. Upon completion of the shoreline renovation, the estimated kill consisted of 46 largemouth bass; 46 black crappie; 6,066 bluegill; 50,052 white perch; 516 carp; and 126,678 gizzard shad for a total of 184,304 fish weighing 11,822.6 kilograms or 93.4 kilograms per hectare. A standard survey conducted in August, 1974 to evaluate the results of the partial renovation concluded that the shoreline renovation was unsuccessful in significantly reducing numbers of the target species. Also, no largemouth bass recruitment or improved growth of game species was noted. Survival of stocked walleye was noted, but no survival of stocked striped bass or largemouth bass. Several factors appeared to be responsible for the failure of this renovation to achieve its intended goals. The renovation date was chosen to correspond with the spawning period of white perch, which in Wagon Train occurs during the latter part of May and first part of June. High alkalinity of Wagon Train necessitated delay of the renovation because high alkalinity and pH values accelerate the rate of degradation of antimycin, requiring higher dosages and decreasing the selectivity. Because of the delay, the renovation may not have been completed until after the peak spawning period for white perch was over. Water quality was still not ideal at the time of treatment and relatively high dosage (8 and 10ppb) was necessary, possibly causing a decline in chemical selectivity. Even if antimycin treatments were more predictable and satisfactory control could be consistently accomplished, selective removal may not prove to be a workable solution to overpopulations of white perch. The high reproductive rate of this species and its demonstrated ability to rapidly overpopulate in lakes with established fish populations indicates that the white perch may be capable of recovery to pre-renovation population levels within one or two years. At best, selective controls may be capable of producing only very short term improvement for lakes containing white perch.

Attempts at control of white perch numbers in Stagecoach reservoir through predator stockings also met with poor success. In view of this failure to achieve control over white perch numbers by any means short of total reclamation, it became apparent that complete removal of white perch from Wagon Train and Stagecoach reservoirs was the only option remaining if the sport fisheries of these reservoirs were to be restored.

A total reclamation of Wagon Train reservoir and its watershed using rotenone was conducted in August, 1975 after the reservoir level had been lowered. Lowering the reservoir made this endeavor economically feasible and to date indications are that all fish were killed. Stagecoach reservoir was also totally reclaimed in August, 1976 to reduce the probability of white perch being dispersed into other reservoirs of the watershed.

Prior to both renovations white perch escaped from Stagecoach and Wagon Train reservoirs, through the outlet structure, into Salt Creek, a tributary of the Platte River. The presence of white perch has been confirmed in both the Platte and Missouri Rivers (Bliss and Schainost 1973 and Hergenrader 1980). Although reproduction of white perch in rivers and streams of Nebraska has not been confirmed (Maret 1978), it is known that white perch are established in at least some areas of the river systems to which it has gained entry. Owing to their apparent widespread distribution, the elimination of white perch from eastern Nebraska would therefore prove to be very difficult, if not impossible.

Walgren Lake in northwestern Nebraska (Sheridan County), was totally renovated with rotenone in July, 1978. This reclamation eliminated white perch from its known western most lake environment in Nebraska. Sampling of this lake in the two years since the renovation substantiated no survival of white perch. Buckley 3F, a Natural Resources District (NRD) lake, in the Little Blue River Basin was likewise totally reclaimed in July, 1980. Consequently, remaining lake populations of white perch in the state as of 1981 are the Offut Air Force Base and Waconca lakes adjacent to the Missouri River. Scattered samplings of white perch in sand pits adjacent to the Platte and Missouri River have been documented (Hergenrader 1980) and should not be discounted, since dispersal during spring flooding offers potential for white perch invasion of other bodies of water presently uninhabited by this species.

At the present time, management of white perch in Nebraska means chemical renovation of those waters supporting stunted populations. This is costly in terms of man-power and the destruction of existing fisheries.

Management approaches for waters supporting white perch vary from location to location and depend to a large degree on the management objectives and species inhabiting the aquatic environment with white perch. This species is adaptable to a host of different habitats (fresh or saltwater, stream or lake, large or small) but generally it has a tendency to overpopulate and stunt in standing bodies of water. Cantele (1971) and Moulton (1972-1976) reported a decline of age I+ and age II+ (51 - 104 mm) white perch numbers in Bantam Lake, Connecticut due in part to the stocking of northern pike. This predator was initially stocked in 1971 in this lake which contained a stunted white perch population. Through natural reproduction a native population of northern pike was established which utilized white perch. As a result, the white perch population stabilized and the growth rates of younger year classes increased by 1976.

In other states management endeavors have varied. Fuller and Cooper (1946) advocated population control in Maine waters using poison and netting. In bass and white perch lakes management should be for largemouth first and perch second. In white perch and pickerel lakes white perch should be controlled. Reid (1972) suggested that crawfish *Orconectes limosus* may be worthy of consideration in introducing as a supplemental forage organism for larger white perch in waters managed for salmonids where white perch predation upon rainbow smelt was thought to be reducing salmonid production. Hilton (1977) claimed Maine has 398 lakes containing white perch. Unlimited harvest with no size or bag limits were considered good management moves. Similar regulations with no seasonal restrictions were implemented in Rhode Island waters (Saila Horton 1957) in 1957 and recent strategies included no stockings of white perch (Guthrie and Stolgitis 1977). On Urieville Lake in Maryland, Sanderson (1959) recommended the licensed use of trap nets by state fishermen, management recommendations from biological investigations, eradication of the fish population, stocking adult bass, and educating the angler as potentials to deal with white perch in this 86 ha lake.

In Massachusetts management of white perch in lakes, ponds, and reservoirs included direct and indirect means of control. Direct control measures included netting, spawn destruction, poisoning, and draining. Indirect controls were habitat improvements, stocking predators in certain areas, modernization of legislation and education of the angling public (Stroud 1952). Grice (1957) used fyke nets to thin populations of white perch in Massachusetts ponds. Although this did not create a better gamefish population, it was temporarily effective in increasing the average size of panfish. In other parts of white perch range Hurley and Christie (1977) postulated that white perch proliferated in the Bay of Quinte, Ontario after invasion because of a lack of suitable predator numbers.

Other examples similar to those reported above are available in the literature. Another possibility, and one which might be pursued further, involves utilization of hybrid white perch in small impoundments. In particular the progeny produced from a female striped bass crossed with a male white perch are capable of attaining weights in the two to three pound size class. They will also take natural baits (J. H. Kerby pers. comm.).

A thorough evaluation of all aspects of white perch biology and population dynamics should be conducted before this species is intentionally introduced elsewhere. Since the extermination of white perch in Nebraska is unlikely, management endeavors will have to be on a case by case basis taking into consideration the objectives of the managing entity.

SUMMARY AND RECOMMENDATIONS

White perch have been present in Nebraska since 1964. Viable populations, prior to reclaimation efforts, existed in Walgren, Wagon Train, Stagecoach, and Buckley 3F reservoirs. To date, eradication efforts utilizing rotenone have proven to be effective, but costly in terms of money and lost angling opportunity during interium stocking years. It is known that white perch now exist in some sandpits adjacent to the Platte and Missouri Rivers. Most noteworthy of which is Waconda, Offutt Air Force Base, and Ridgewood, all located in the east central border area close to Omaha, Nebraska. One sexually mature male was also sampled in Pawnee Lake in May, 1980 and attests to the fact that white perch may again become prevalent in the Salt Valley watershed reservoirs surrounding Lincoln in the future.

White perch have principally been studied in Wagon Train and Stagecoach reservoirs and to a lesser extent Buckley 3F reservoir. During the time period populations existed some aspects of this species were examined. Most noteworthy of which are as follows: White perch achieved an average total length of 102 mm-127 mm by age 1 and 229 mm by age III in Wagon Train and Stagecoach reservoirs. This is rapid growth compared to the growth achieved by this species in its native range. Although growth was good, very few white perch lived beyond the age of three years in Wagon Train and Stagecoach reservoirs. Natural mortality was high in both reservoirs after age II. Consequently, relatively few individuals reached a size considered acceptable to the angler.

A length-weight relationship was calculated from data obtained from 2370 white perch. The length-weight equation is: $[\log W = -4.594 + 2.89 \log L]$ (where W = weight in grams, L = total length in millimeters).

In 1973 and 1974 annulus formation of white perch, ages I-III, occurred in the months of April through July. Water temperatures during this period ranged from 12.8°C on April 17, 1973 to 23.3°C on July 24, 1973 and from 12.2°C on April 11, 1974 to 28.9°C on July 23, 1974.

White perch spawned in Stagecoach and Wagon Train reservoirs during the months of May and June with the peak period being the last week of May through the first week in June. No habitat preference was noted other than the fact that it occurred in shallow water. Water temperatures during this spawning period ranged from 14.4°C on May 8, 1973 to 21°C on June 6, 1973 and from 18.3°C on May 8, 1974 to 22.2°C on June 12, 1974.

In its native range white perch become sexually mature during the second year of life and spawn for the first time during the spring of their third year. In Nebraska, they reached sexual maturity and spawned at one year of age or at an approximate length of 127 millimeters.

Fecundity was estimated from 18 Wagon Train white perch ranging in total length from 112-307mm and 15-499 grams in weight. Estimated total number of ova ranged from 6,256 to 113,952 with a mean fecundity of 34,746. Thirty-four age II white perch were also analyzed for fecundity from Stagecoach reservoir. Estimated total number of ova ranged from 16,374 to 463,720 with a mean fecundity of 167,462. Ova diameters ranged from 0.4-0.7 mm for age I fish with a mean of 0.6 mm. Age III fish had a range of 0.3-0.7 mm diameter with a mean of 0.5 mm.

High coefficients of determination (R^2) were derived from the Wagon Train fecundity data. When analyzed separately weight, length, and age accounted for 89%, 87% and 88% respectively of the variation in fecundity. Of these three variables, multiple regression using weight and age combined produced a highly significant R^2 value of 0.90.

Food habit information collected from Stagecoach indicates white perch age I-III consumed primarily immature aquatic insects, especially dipteran larvae. Four white perch were found in three white perch stomachs, indicating that fish were not a substantial constituent in their diet.

Early sexual development, the ability to spawn in a variety of habitats, and a high reproductive potential could very well explain the unusually rapid expansion of white perch numbers noted after their entrance into Wagon Train and Stagecoach reservoirs and may be the cause of their apparent tendency to overpopulate most landlocked reservoirs in which they gain entry.

Attempts to manage white perch in Nebraska have boiled down to chemical renovaton of those waters inhabitated by this species. In other areas of it's range direct as well as indirect control measures have been used. Since the extermination of white perch in Nebraska is doubtful, management endeavors will have to be on an individual basis depending upon where it appears next. If hybrid (female striped bass x male white perch) white perch had a very low reproductive potential they would be worthy of consideration for stocking in small impoundments as they will take live bait and are capable of attaining weights in the two to three pound size range. The best recommendation for white perch is that this species should not be intentionally stocked in any standing body of water.

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The following list of bibliographic sources were used in preparation of this bibliography: Biological Abstracts; Zoological Record; A Bibliography of Fishes by Bradford Dean, 3 vol.; Dean Bibliography of Fishes by James W. Atz; Current References in Fish Research by Victor Cvancara; Bibliography of Thesis on Fisheries Biology, 1959 and 1959-1971.

Computer search in the following data bases were done: Biosis Previews (Biological Abstracts); NTIS (National Technical Information Service); Pollution Abstracts; Dissertation Abstracts; Aquatic Sciences Abstracts; Enviroline (Environmental Abstracts).

In addition, the bibliography in each white perch thesis and paper was used for citation sources. The CBE Style Manual, Third Edition, was used for bibliographic style entry. Biosis List of Serials, 1976 was used as much as possible for abbreviation of serial titles.

Bibliographic entries with asterisks before the author's name have not been seen. These citations are written, for the most part, as they were found in other bibliographies. Some of the entries that have not been perused may not have references to white perch. Since all entries could not be verified, titles were included that seemed most likely to mention white perch.

An asterisk (*) before an entry indicates that it has not been seen by this author.

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